SCIENTIFIC AMERICAN MONTHLY

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CLEARING CANADIAN CITY STREETS OF SNOW—REAR VIEW OF A HORSE-DRAWN, POWER-OPERATED SNOW PLOW (SEE PAGE 252)

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DO CALORIES MEASURE THE VALUE OF FOOD?*

BY HENRY DWIGHT CHAPIN, M.D.

As the attention of physicians is being called more and more to problems of nutrition and their solution, it may not be out of place to re-examine some of the foundations of our teachings and see if they are altogether sound.

CALORIES AND FOOD VALUES.

Much is written and said about calories, as the food value of a certain substance is so many calories; and there is a suggestion that a calory is a sort of food ingredient, the real value of food depending on the number of calories present.

A calory is a measure of heat, just as grams, ounces or pounds are measures of weight. If a table of food values was prepared which stated that a definite quantity of milk yielded 6 pounds, meat 8 pounds, bread 4 pounds, and soup 1 pound, the natural question would be, "Pounds of what?" Scant attention would be paid to any one dwelling on the value of particular foods, because the pounds were there. Is it any more rational always to dwell on the value of a definite quantity of food simply because it contains so many calories? The most diverse kinds of food may have the same caloric value but a very different nutritive value.

The calory method of feeding is based on the assumption that nutrition processes depend solely on the oxidation of food, and that the heat given off as the result of the oxidation is the sole measure of the value of the food. In practice, the tendency is to keep a table of calory values from which a diet is made out by an arithmetical process, and the physician is likely to feel that if the calory count is correct, the food problem is properly solved.

In experimental nutrition, however, it is soon found that nutrition is not a simple oxidation process. Many feeding experiments have been conducted with animals to see if food materials from different sources, having supposedly the same chemical composition and yielding the same number of calories as the result of oxidation, have the same practical food value. One of the most notable of these experiments was made by Hart McCollum, Steenbock and Humphrey[1] at the Wisconsin Agricultural Experiment Station with a large number of animals over a period of four years, and some of their remarks and conclusions make interesting reading. They say, in part:

"There is evidence from the data that there is a distinct and important physiologic value to a ration not measurable by present chemical methods or dependent on the mere supply of available energy. While the latter are important and give valuable data for a starting point, they are, nevertheless, inadequate as final criteria of the nutritive value of a feed. . . . Probably none have felt the limitation of mathematically constructed feeding standards more than those who have taken a prominent part in their development, and even the practical and successful feeder uses these standards only as a help, varying the kind, as well as the proportion of total nutrients in the ration to meet the requirements of the individual. The kind of nutrients, however, receives his attention only when their effects are extremely pronounced and immediately apparent. . . . But in addition to the limitation of mathematical standards, which consider only digestible nutrients, or the total net available energy of a ration, there are still other important factors that must be considered. We refer to what may be called the *physiologic value* of the ration. . . . There are many different proteins, in addition to nitrogen-bearing bodies of nonprotein character; fats of different compositions and degree of saturation; carbohydrates of many types; and almost a host of undetermined and undefined bodies in the daily ration of a domestic animal. . . . Unquestionably the *physiologic* value of a ration is largely dependent on its chemical constituents, but the usual determinations made on feeding materials do not reveal the character or manner of combination of many of the constituents. Consequently, the physiologic value can be determined in the present state of our knowledge only by long continued observations of the reaction of the feed on the animal."

Since the foregoing experiments were conducted, animal feeding experiments have been widely carried on, and it seems to be the universal finding that the number of calories a food yields on oxidation is not at all an indication of its feeding value. Bayliss[2] says:

"Heats of combustion do not necessarily give the actual energy value of foodstuffs as available in the organism. . . . In the animal body, energy is derived from chemical combination. This form of energy is readily converted into various other forms without the necessity of passing through the form of heat."

ANAEROBIC AND AEROBIC REACTIONS.

At this point it may be well to call attention to a fact not generally known, namely, that large quantities of the common foods are used by animals by anaerobic metabolism, since air is not essential to animal life in all cases. Mammals and birds quickly die from lack of oxygen. Frogs may remain alive for days in an atmosphere containing no oxygen. Fish and reptiles may live without air for some time, while insects

*Read before the American Pediatric Society, Atlantic City, N. J.

[1] Research Bull. 17, University of Wisconsin Agricultural Experiment Station.

[2] Bayliss, W. M.: Principles of General Physiology, New York, Longmans, Green & Co., 1915.

will live and be active in a vacuum for several days. Leeches can live ten days without oxygen. Bunge[3] says:

"I have made many experiments with the roundworm of the cat, and have satisfied myself that these animals can live in media entirely free from oxygen for from four to five days and be extremely active during the whole time. Whoever has seen these movements must be convinced that oxidation is not the source of muscular energy in these animals."

It is evident that animals which eat the common foodstuffs and obtain energy from them for days at a time in the absence of oxygen do not carry on their vital processes and obtain energy as the result of oxidation, and that for them the amount of heat that can be produced by oxidation of the food they utilize is of no interest.

In the bodies of higher animals it appears that the processes of nutrition are a combination of anaerobic and aerobic reactions. From reading Bayliss it would seem to be fairly well settled that the primary processes in the bodies of higher animals are anaerobic, and that the aerobic processes are secondary. The contraction of the muscles is an anaerobic process:

"There is neither consumption of oxygen nor evolution of carbon dioxid. It is not an oxidation process. . . . To restore the potential energy which the system has lost in contracting, energy is supplied by another reaction of a chemical nature, which succeeds the contractile stage. . . . The energy required for the second process is afforded by a reaction in which some substance, carbohydrate or fat, is oxidized. Much oxygen is used and carbon dioxide given off. . . . Consideration of life without oxygen leads to the view that the actual source of the free energy required by a living organism is a secondary matter. If it cannot be obtained by oxidation, other chemical reactions, although of a less efficient kind, are made use of."

If this is the case, it is easy to understand how the large number of animals that can live without oxygen obtain their energy—they simply use more food and discard it at the point at which oxidation begins in the aerobic animals.

VALUE OF THESE FACTS TO THE PHYSICIAN.

These facts are of much importance to the practicing physician. He is required to solve numerous problems which call for the selection of food of the right *physiologic value* for a given individual. What may be the right physiologic value for one may not be suitable for another. It is possible that the difficulty lies in a perversion of anaerobic metabolism in one case and aerobic metabolism in another. It has been conclusively shown that in practice the caloric value of a food is no strict indication of its nutritive value, but it has not been shown why this is so. With the recognition of the fact that an animal body is not merely a furnace in which food is burned, but that a long series of chemical changes in the food takes place, it is not difficult to see why practical results often cannot be obtained with foods valued only by their oxidation properties. To quote Bayliss again:

"The general conclusion seems to be justified that the cell mechanisms are such as to be able to use chemical energy whether it comes from oxidation or otherwise, and that they are independent of the particular chemical reaction which affords it."

The animal body is highly complex, with a metabolism that is in part anaerobic and in part aerobic, as some tissues live by the former process and others by the latter.

SUMMARY.

Heat or energy may be produced by chemical cleavage as well as by oxidation. Heat may be a degradation of energy, and in the human organism it is an excretion. Heat measurement alone is not a safe guide for the calculation of food values. This is especially true at the beginning of life when growth is the all-important factor. The foods that *build* rather than those that readily undergo oxidation must be properly gaged if we are to have healthy development. Some form of biologic testing of foods must be elaborated if an always reliable gage of nutrition is to be established.

[3]Von Bunge, Gustave: Text-Book of Physiological and Pathological Chemistry, Philadelphia, P. Blakiston's Son & Co., 1902.

THE REGENERATION OF USED LUBRICATING OIL.

IT was long considered impossible to regenerate lubricating oils because it was believed that they had undergone a necessary loss of lubricating power in the course of their employment. This has now been proved not to be the fact. The French scientist, M. Riallaud, has just investigated a physico-chemical process which gives excellent results. As described in the July-August number of *Les Annales des Falsifications et des Fraudes*, the process is as follows:

Used lubricating oil contains three kinds of impurities:

1. Very minute metallic particles, the smallest of which may have only 1/3 of a micron for their largest dimension;

2. Particles of carbon of about the same size as the foregoing, these being especially frequent in the oils coming from explosion motors;

3. True metallic soaps result from the combination of the metals and the fatty acids proceeding from the original lubricants when the latter are of organic origin, like castor oil. In the case of mineral oils compounds analogous to the naphthenes appear to be formed. These two kinds of compounds, which are very unstable, are readily decomposed by heat, and when thus decomposed they deposit upon all heated points metal oxides which possess abrasive properties similar to those of carbon particles.

These particles of carbon or metal are visible under the microscope and they impart to the alloys in which they are found either some coloration or a certain degree of turbidity; the metallic compounds may, however, be found in an oil which is perfectly clear.

No purely physical process is capable of completely removing these impurities since the first set of particles are too small while the second are soluble. M. Riallaud has recourse, therefore, to a veritable "sizing" analogous to that of wine and beer. Two aqueous liquids are prepared, one of which consists of dilute sulphuric acid, while the other contains caustic soda, tannate of soda and gelatine, the latter being obtained from tannate of soda by means of a large excess of soda lye. This excess and the concentration of the first liquid must be such that upon mixing together equal volumes of the two liquids the mixture will continue to remain acid. Under these conditions sulphate of soda will be formed, while the tannin combines with the gelatine to form a mucilagenous precipitate.

After heating the oil to be regenerated in order to render it more fluid, about 5 per cent of its own volume of the first liquid is added—this volume being dependent upon the degree of concentration and the content of impurities; the mixture is then vigorously stirred, whereupon the naphthenes and the fatty acids of the metallic compounds are set free; there will be formed the sulphates of the metals which they contain and which remain in the aqueous solution. An equal volume of the second liquid is then immediately added, the stirring being continued vigorously, thereupon the aforesaid combination of the tannin and the gelatine will take place. This mucilagenous precipitate carries down with it the minute particles of metal and of carbon, and even portions of the sulphates produced, especially of the sulphate of soda. The density of the gelatinous particles thus formed is so great that density of the gelatinous particles thus formed is so great that upon decantation they are rapidly separated from the liquid.

The mixture is decanted while hot and then filtered, still while hot, in order to separate such particles as have not been deposited by the decantation. The regenerated product is found to possess the same qualities as the original oil with the exception merely that the index of saponification of vegetable oils is somewhat diminished.

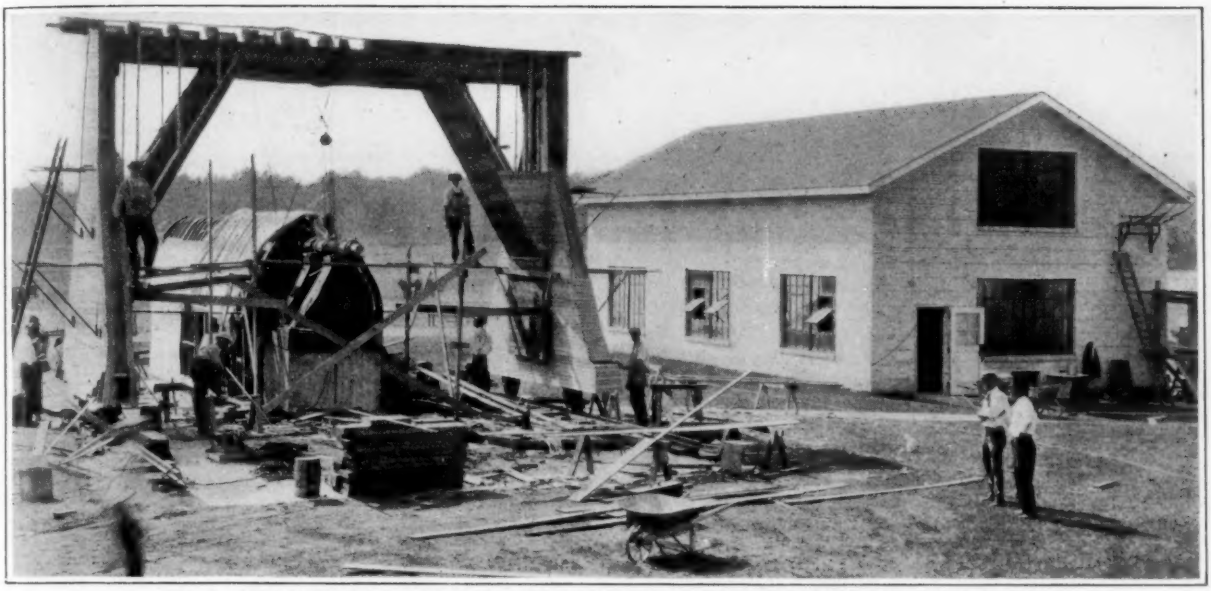


FIG. 1. THE JACKSHAFT BEING LOWERED INTO PLACE IN THE PROPELLER-TESTING PLANT

Propeller Testing Laboratory at McCook Field*

An Elaborate Plant of the Army Air Service

By F. W. Caldwell, Aeronautical Engineer, Air Service, U. S. Army

THE Army Air Service has put into operation at McCook field a propeller testing laboratory that is believed to be the most powerful and complete plant of its kind in the world. The existence of this laboratory and the scope and character of the work done there are almost unknown among aeronautical engineers and others interested in the aeronautical industry. This is primarily due to the necessary conservatism which has governed in making public military activities during the war.

The purpose of this article is to give a description of the laboratory equipment and of the scope of the tests that are carried out there.

This plant was erected in order to safeguard the experimental propellers against the possibility of failure in the air and at the same time to make tests of promising inventions and designs.

Serious propeller failures have been so rare with the Army during the last two years that many persons do not realize the damage that is usually caused by them. The fact that these accidents have been so rare is largely due to the policy of not allowing any propeller to go into the production until the design has been standardized. This process always includes a destructive whirling test of at least one propeller of the design made of the wood which is proposed for production. The test given is an overload test, the amount of overload and the endurance of the test being varied at the discretion of the engineering department; for most wooden propellers, however, a test of ten hours at an overload of 50% is sufficient to insure an ample factor of safety.

Anyone who has seen the results of a bad propeller failure need not be told of the effect. It is only necessary to imagine an unbalanced centrifugal force of 30,000 lbs. resulting from the loss of one of the blades; with this centrifugal load changing its direction with each revolution it is only a matter of good fortune if the whole machine is not wrecked.

*Reprinted from the *Aerial Age Weekly*.

In designing this testing laboratory a number of sources of power were considered. At the start we laid down the following specifications for the design: (1) the plant must be capable of developing a maximum power of not less than 2,200 horse-power; (2) it must be provided with an accurate speed control up to the maximum speed of 3,000 r.p.m.; (3) provision must be made for accurately weighing the thrust and torque; (4) a bombproof must be provided for catching the flying parts of broken propellers and the bombproof and the base of the power plant must be arranged in such a way as to minimize the interference with the flow of air through the propeller; (5) provision must be made for an observation chamber protected from the flying parts; (6) suitable equipment must be provided for measuring the deflection of the propeller while it is turning.

A number of different ways of furnishing the power for the operation of the propeller shaft were investigated. The steam turbine offered the objection that a large steam boiler equipment was required and the horse power delivered could be only approximately estimated from the bowl pressure. The alternating current electric motor did not offer satisfactory speed control. No standard type D. C. electric motor of this power and speed could be located and we were assured that considerable trouble with commutation would be encountered with a direct current motor of such high speed. Direct current motors of lower speed were available and estimates were obtained on gearing to step the speed up. The time required for delivery was considered impractical.

Meanwhile it was found that a number of Sprague dynamometers rated at 200 to 300 horse-power were available. These can be run at 200 horse-power continuously if proper cooling is provided, and can be run for a few minutes at 300 horsepower.

The Sprague machines offered all the advantages of great speed range, accurate control, and accuracy of power measurements. Furthermore, the Sprague machines, being of

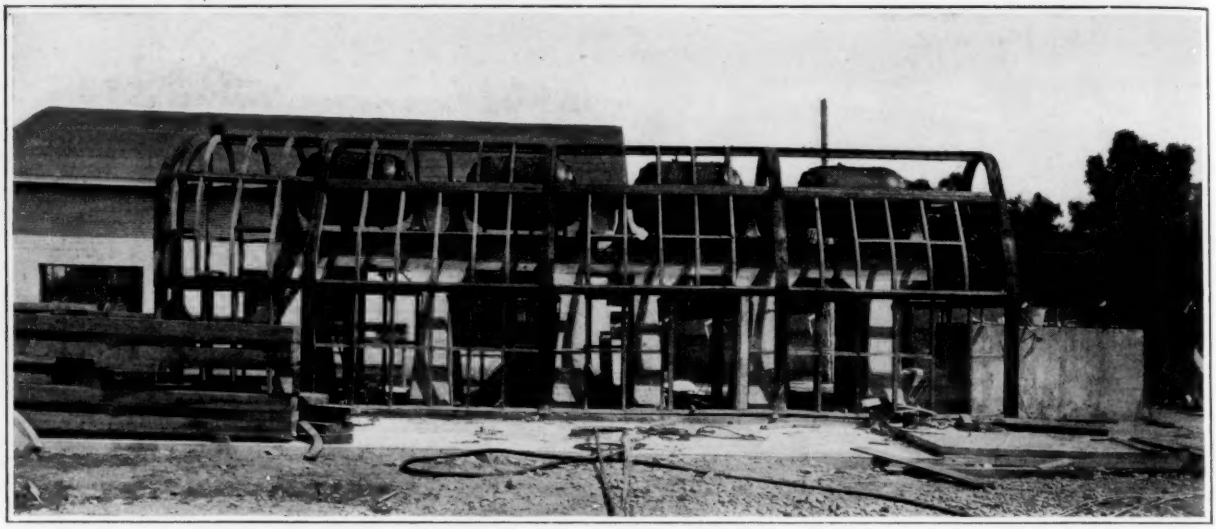


FIG. 2. THE FOUR SPRAGUE TESTING DYNAMOMETERS

smaller diameter, could be streamlined in such a way as to interfere as little as possible with the propeller blast. It was found that sufficient power could be obtained by the use of four of these machines in a row.

The arrangement of the four Sprague machines can be seen in Fig. 2. This photograph, taken during the course of construction, shows the concrete supports for the motors and the framework of the concrete housing. At the right hand end of the picture is shown the massive foundation of the jackshaft pedestals. The motors are joined by Francke couplings of ample size. These couplings have given no trouble whatever.

Figure 1 shows the jackshaft being lowered into place. This jackshaft is a six-inch nickel steel shaft. This size and material have been found necessary to withstand the shocks imposed by a suddenly breaking propeller. To further reduce the shock a shaft extension is provided. This extension is bolted on the shaft end by means of four ⅝-inch bolts. These bolts are drilled out inside to 5/16 inch. If a propeller breaks near the hub on one blade the unbalanced centrifugal force breaks the bolts and the shaft is not injured.

The archlike bombproof shown in Fig. 1 is being used as a crane. It is provided with wheels and a track and serves to move any of the motors or parts when required. The manner in which it serves as a bombproof is more apparent in Fig. 3. In this figure also may be seen the observation slots which lead down to the observation chamber. In order to avoid the possibility of broken particles flying through these slots into the observing room, observations are always taken on the side of the axis where the propeller blades are moving upward. On the other side the slots are covered with a piece of boiler plate.

As the bits of broken propellers fly out almost exactly in the plane of revolution it was not found necessary to make the bombproof very wide. At the right of the picture in Fig. 1 can be seen the brick power house. This contains the motor generator set which furnishes direct current and contains a small shop for adapting experimental propellers for testing as well as an office for the engineer in charge of the testing plant. A thorough description of each test is kept here and it is possible to refer to any past test and find photographs and all details of the test.

The 1,000 K. W. motor generator set is used which is a standard Westinghouse equipment. The size of this machine is ample and the power is great enough to provide for any probable future requirements in the way of increased size of the testing motors. At the rear of this machine are the contactors through which the power input to the Sprague motors is regulated. These contactors are operated by means of remote controls which are located in the observation chamber underneath the propeller shaft. Alternating current is furnished by a local power company at 6600 volts. The normal voltage of the D. C. generator is 550, but the voltage is varied according to the speed at which it is desired to turn the Sprague motors, as this method is economical of power and the current from the generator is not used for the operation of any other machines.

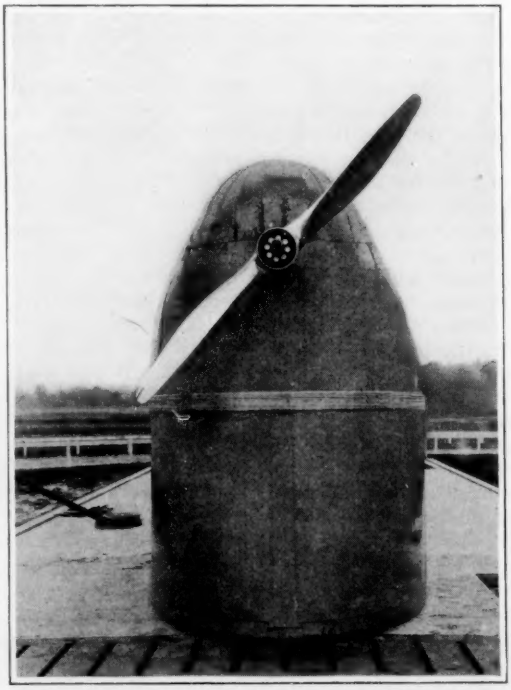


FIG. 3. PROPELLER TEST RIG SHOWING A PROPELLER IN POSITION FOR TEST. NOTE THE OBSERVATION SLOTS IN THE FLOOR BELOW THE PROPELLER

Returning to the description of the testing plant proper a drawing of the principal members is shown in Fig. 4. The flexible couplings between the motors are the well-known Francke couplings, and, being of ample size, they have never required any attenion since they were installed.

The floating coupling between the motors and the propeller shaft acts as a flexible coupling and at the same time must allow the propeller shaft to move axially ¾ inch in either direction without transmitting any thrust to the motor shaft. This requirement

was so unusual that a new type of coupling had to be designed. The original design gave a little trouble in eliminating all of the thrust; a later design, however, appears to give very satisfactory results.

The scale mechanism was designed and built by the Toledo Scale Co.

The torque is applied to torque bellcranks (Fig. 4) by means of short links. The torque bellcranks are all tied together by means of horizontal links so that the total load from all the machine is applied to the bellcrank nearest the scales. Here an ingenious device maintains tension in the vertical torque scale rod shown under the floating coupling no matter which way the motors are turning.

The thrust bearing is a standard Kingsbury bearing and need not be described here. The thrust is transmitted to a bellcrank and again to a vertical scale rod which is maintained in tension regardless of the direction of the thrust.

serves as a very convenient means for balancing the load.

Just above the scales may be seen the observation slots in the roof of the room. These slots are in the plane of revolution of the propeller and extend all the way across the room.

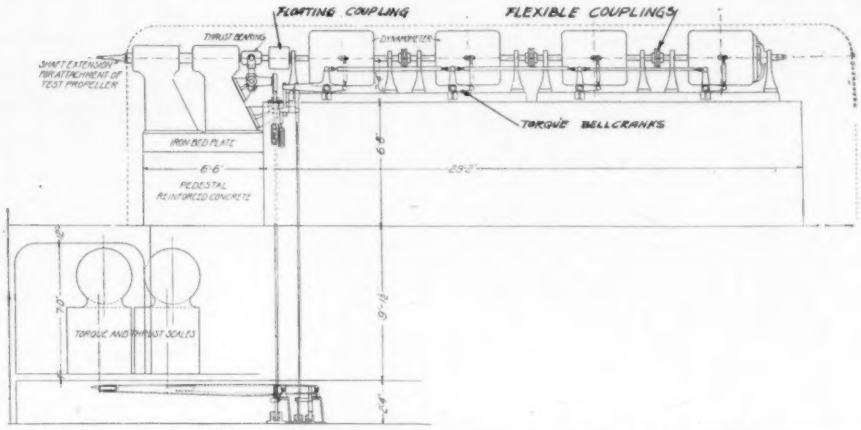


FIG. 4. PRINCIPAL MEMBERS AND DIMENSIONS OF THE DYNAMOMETER WITH TORQUE AND THRUST RECORDING SYSTEM

The observation chamber is located directly underneath the propeller shaft and both torque and thrust scales are located in this room. The scales proper are of the indicating type and are shown in Fig. 6. Each scale has a total capacity of 6,000 pounds, the dials being graduated to show 2,000 pounds for one complete turn.

Between the two scales and at the top is an electric tachometer (Fig. 6) which is used to adjust the revolutions approximately. Exact revolution speed is obtained by means of an ingenious electrical counting device designed by one of the testing staff, Mr. Gray.

At the right of the picture (Fig. 6) is the control panel for the Sprague motors. The motors are operated in two parallel sets, each set comprising two motors in series. The two control handles are arranged to permit operation of the two sets either independently or together. The ammeter near the top of the panel shows the current of each set and it

By close inspection of Fig. 5 these slots may be seen at the extreme top edge. At the time this picture was taken all of the slots had been provided with felt-lined trap doors in order to minimize the noise in the room. Any of these doors may be opened when an observation is to be made and one of the doors is shown held open in the picture.

The transit telescope shown here serves to give accurate readings of the axial deflection of the propeller blade at any radius. The telescope is provided with a mirror set at 45 degrees so that the revolving propeller may be seen through the slot by looking into the telescope.

The sliding ways on which the telescope is mounted are set up exactly parellel to the axis of the propeller shaft. Thus the telescope is exactly parallel to the plane of revolution of any radial element of the propeller. When the propeller is turning over at idling speed the telescope is adjusted until the cross hair is exactly in the plane of revolution of,

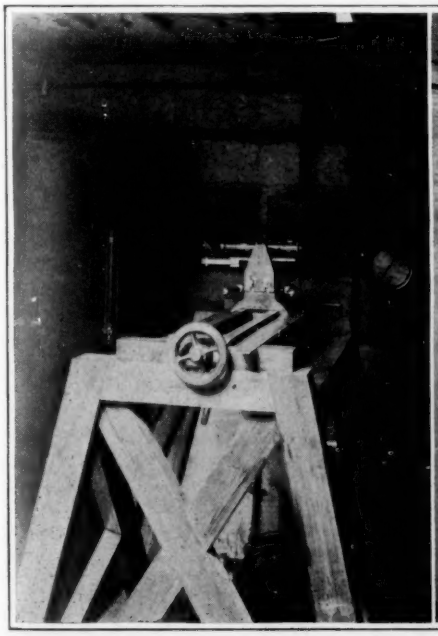


FIG. 5. TRANSIT TELESCOPE AND MIRROR FOR OBSERVING DEFLECTIONS OF PROPELLER SPEED

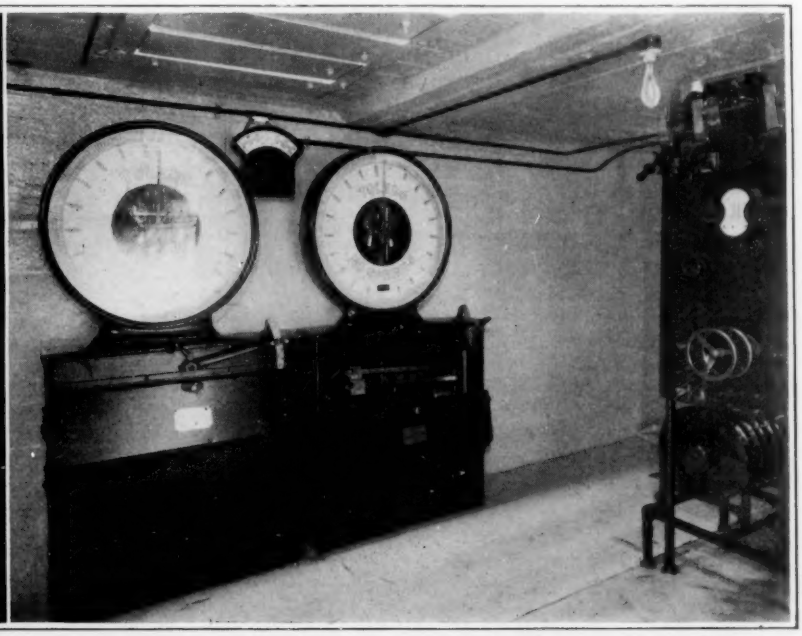
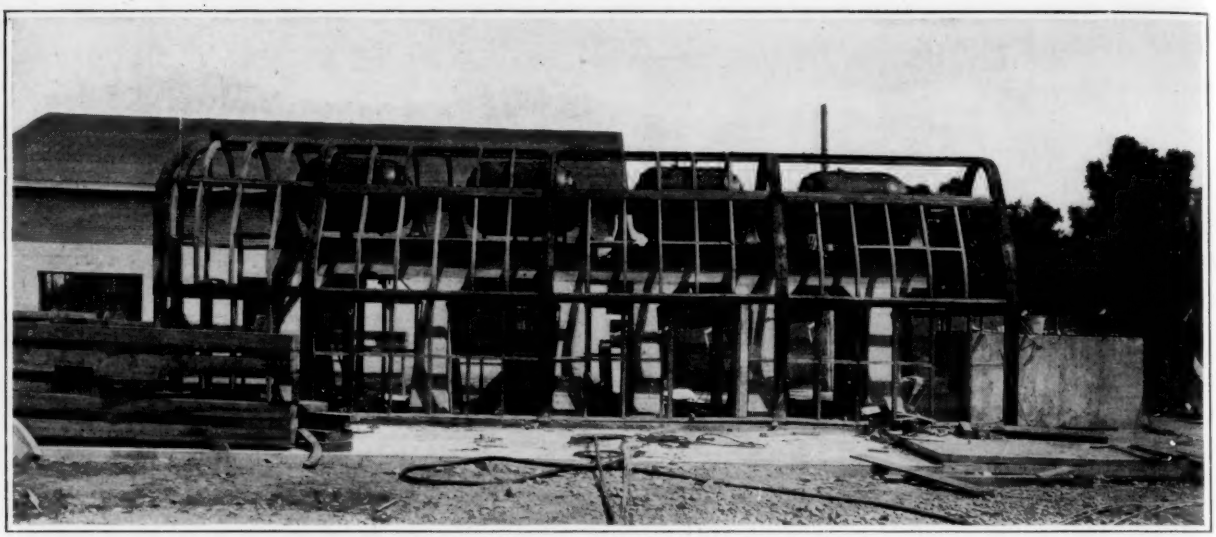


FIG. 6. TORQUE AND THRUST DIALS IN UNDERGROUND OBSERVATION ROOM WITH DYNAMOMETER CONTROL SWITCHBOARD



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The archlike bombproof shown in Fig. 1 is being used as a crane. It is provided with wheels and a track and serves to move any of the motors or parts when required. The manner in which it serves as a bombproof is more apparent in Fig. 3. In this figure also may be seen the observation slots which lead down to the observation chamber. In order to avoid the possibility of broken particles flying through these slots into the observing room, observations are always taken on the side of the axis where the propeller blades are moving upward. On the other side the slots are covered with a piece of boiler plate.

As the bits of broken propellers fly out almost exactly in the plane of revolution it was not found necessary to make the bombproof very wide. At the right of the picture in Fig. 1 can be seen the brick power house. This contains the motor generator set which furnishes direct current and contains a small shop for adapting experimental propellers for testing as well as an office for the engineer in charge of the testing plant. A thorough description of each test is kept here and it is possible to refer to any past test and find photographs and all details of the test.

The 1,000 K. W. motor generator set is used which is a standard Westinghouse equipment. The size of this machine is ample and the power is great enough to provide for any probable future requirements in the way of increased size of the testing motors. At the rear of this machine are the contactors through which the power input to the Sprague motors is regulated. These contactors are operated by means of remote controls which are located in the observation chamber underneath the propeller shaft. Alternating current is furnished by a local power company at 6600 volts. The normal voltage of the D. C. generator is 550, but the voltage is varied according to the speed at which it is desired to turn the Sprague motors, as this method is economical of power and the current from the generator is not used for the operation of any other machines.

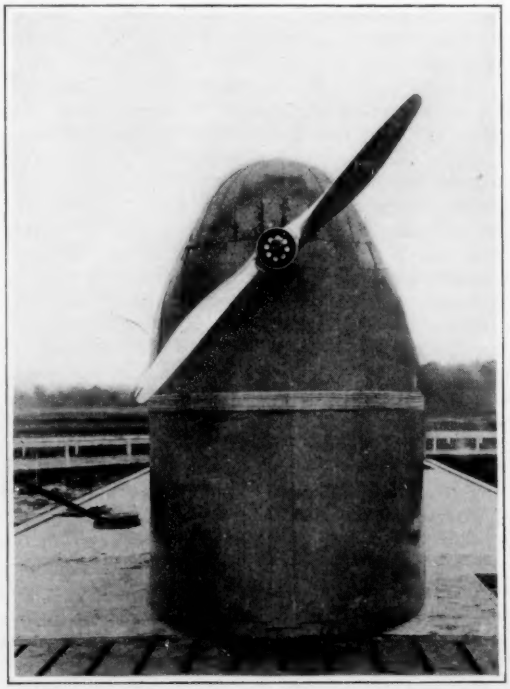


FIG. 3. PROPELLER TEST RIG SHOWING A PROPELLER IN POSITION FOR TEST. NOTE THE OBSERVATION SLOTS IN THE FLOOR BELOW THE PROPELLER

Returning to the description of the testing plant proper a drawing of the principal members is shown in Fig. 4. The flexible couplings between the motors are the well-known Francke couplings, and, being of ample size, they have never required any attenion since they were installed.

The floating coupling between the motors and the propeller shaft acts as a flexible coupling and at the same time must allow the propeller shaft to move axially ¾ inch in either direction without transmitting any thrust to the motor shaft. This requirement

was so unusual that a new type of coupling had to be designed. The original design gave a little trouble in eliminating all of the thrust; a later design, however, appears to give very satisfactory results.

The scale mechanism was designed and built by the Toledo Scale Co.

The torque is applied to torque bellcranks (Fig. 4) by means of short links. The torque bellcranks are all tied together by means of horizontal links so that the total load from all the machine is applied to the bellcrank nearest the scales. Here an ingenious device maintains tension in the vertical torque scale rod shown under the floating coupling no matter which way the motors are turning.

The thrust bearing is a standard Kingsbury bearing and need not be described here. The thrust is transmitted to a bellcrank and again to a vertical scale rod which is maintained in tension regardless of the direction of the thrust.

serves as a very convenient means for balancing the load.

Just above the scales may be seen the observation slots in the roof of the room. These slots are in the plane of revolution of the propeller and extend all the way across the room.

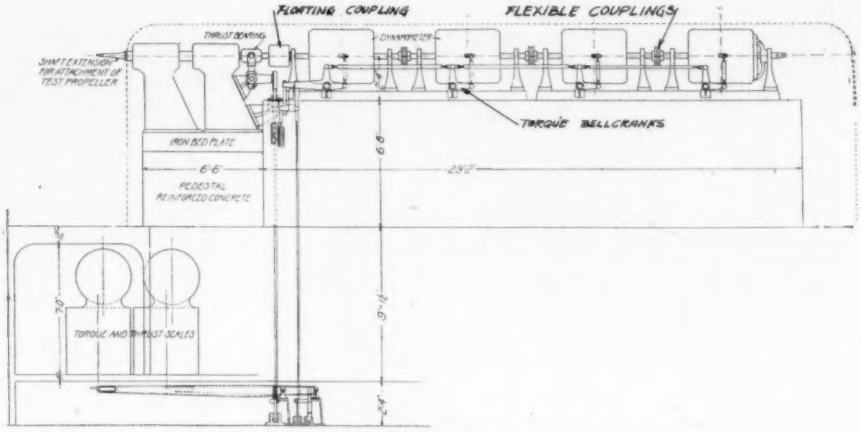


FIG. 4. PRINCIPAL MEMBERS AND DIMENSIONS OF THE DYNAMOMETER WITH TORQUE AND THRUST RECORDING SYSTEM

The observation chamber is located directly underneath the propeller shaft and both torque and thrust scales are located in this room. The scales proper are of the indicating type and are shown in Fig. 6. Each scale has a total capacity of 6,000 pounds, the dials being graduated to show 2,000 pounds for one complete turn.

Between the two scales and at the top is an electric tachometer (Fig. 6) which is used to adjust the revolutions approximately. Exact revolution speed is obtained by means of an ingenious electrical counting device designed by one of the testing staff, Mr. Gray.

At the right of the picture (Fig. 6) is the control panel for the Sprague motors. The motors are operated in two parallel sets, each set comprising two motors in series. The two control handles are arranged to permit operation of the two sets either independently or together. The ammeter near the top of the panel shows the current of each set and it

By close inspection of Fig. 5 these slots may be seen at the extreme top edge. At the time this picture was taken all of the slots had been provided with felt-lined trap doors in order to minimize the noise in the room. Any of these doors may be opened when an observation is to be made and one of the doors is shown held open in the picture.

The transit telescope shown here serves to give accurate readings of the axial deflection of the propeller blade at any radius. The telescope is provided with a mirror set at 45 degrees so that the revolving propeller may be seen through the slot by looking into the telescope.

The sliding ways on which the telescope is mounted are set up exactly parellel to the axis of the propeller shaft. Thus the telescope is exactly parallel to the plane of revolution of any radial element of the propeller. When the propeller is turning over at idling speed the telescope is adjusted until the cross hair is exactly in the plane of revolution of,

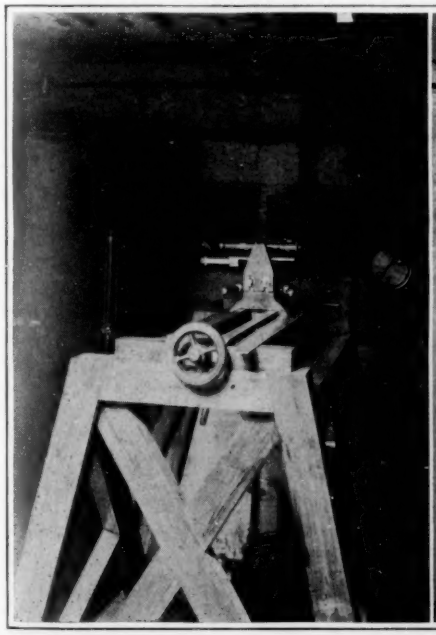


FIG. 5. TRANSIT TELESCOPE AND MIRROR FOR OBSERVING DEFLECTIONS OF PROPELLER SPEED

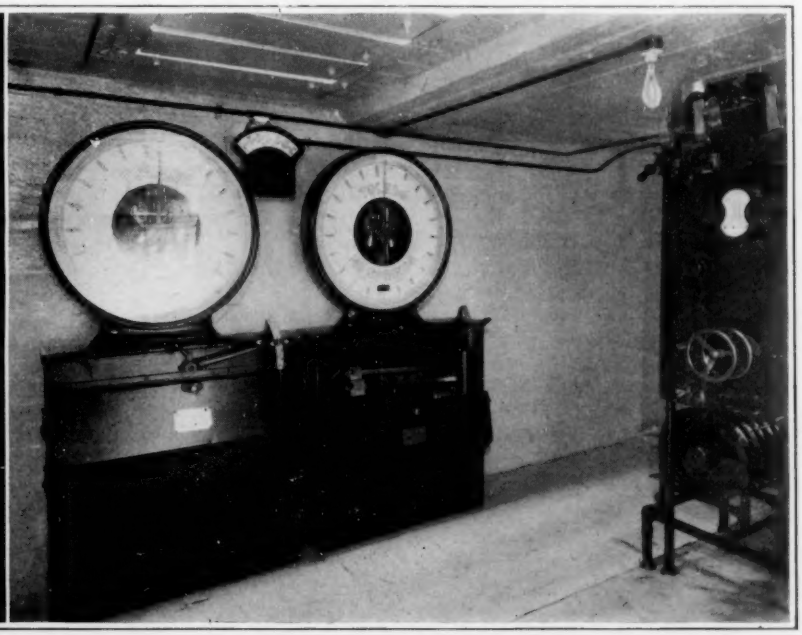


FIG. 6. TORQUE AND THRUST DIALS IN UNDERGROUND OBSERVATION ROOM WITH DYNAMOMETER CONTROL SWITCHBOARD

say, the leading edge. The position of the telescope is then noted on the scale at the right. When the speed is increased, the telescope is again adjusted and the position again noted. The difference of the scale readings gives the axial deflection.

This value is subject to a correction due to movement of the shaft which has to be measured separately and subtracted.

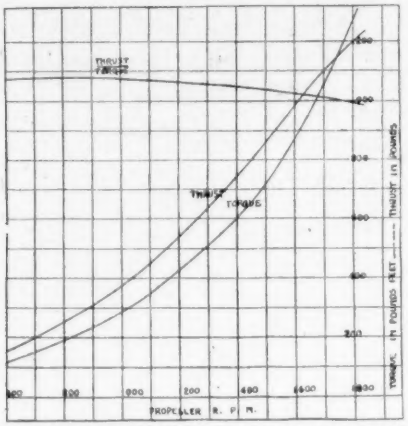


FIG. 7. CHARACTERISTICS OF TYPICAL PROPELLER FROM McCOOK FIELD WHIRLING TEST

By measuring the axial deflection of the leading edge and the trailing edge of a propeller at any point the change in pitch may be obtained by the method shown in Fig. 10.

The present method of measurement gives the average deflection of the two blades. A stroboscopic method is being worked out to give the measurements on the two blades separately.

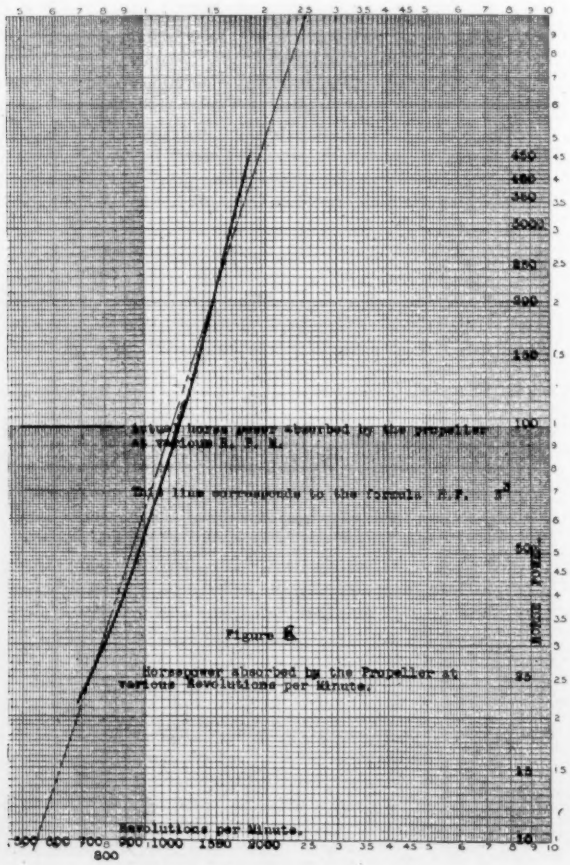


FIG. 8. CURVE SHOWING THE HORSEPOWER OF A PROPELLER AT VARIOUS R. P. M.

Another test which is of great practical value is the water spray test. Two views of a water spray test are given in Figs. 12 and 13. It will be noted from these that the water is supplied from an overhead pipe at the top of the bomb-proof. These tests may be made as severe as desired by regulating the amount of water, the speed of the propeller, and the length of the test.

A typical curve of thrust and torque of a propeller as obtained from this rig is shown in Fig. 7.

If the thrust of the propeller were proportional to the square of the R. P. M. and the torque of the propeller were also proportional to the square of the R. P. M., then the ratio of thrust or torque would be a constant. Since the ratio of thrust to torque is theoretically independent of R. P. M., it is considered a good criterion of the value of a propeller as a thrust producer under given conditions.

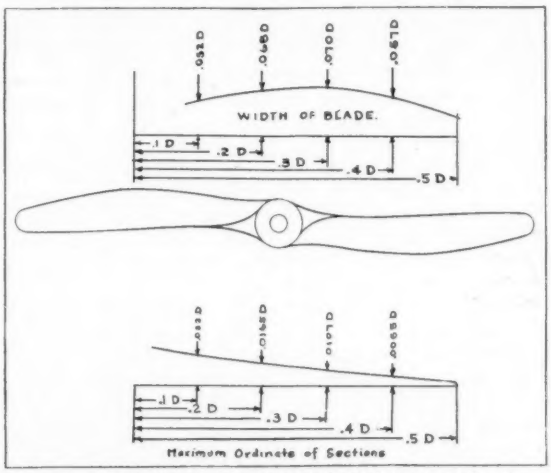


FIG. 9. GENERAL SHAPE OF PROPELLER USED IN TYPICAL TEST

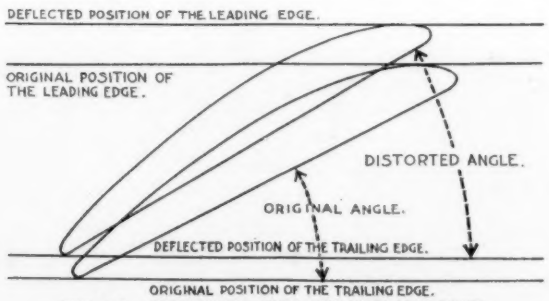

DEFLECTED POSITION OF THE LEADING EDGE.
ORIGINAL POSITION OF THE LEADING EDGE.
DISTORTED ANGLE.
ORIGINAL ANGLE.
DEFLECTED POSITION OF THE TRAILING EDGE.
ORIGINAL POSITION OF THE TRAILING EDGE.

FIG. 10. OBTAINING THE CHANGE IN PITCH

By reference to Fig. 7, however, it may be seen that the ratio of thrust to torque decreases after the speed of 1,000 R. P. M. is reached. This corresponds to a top speed of about 320 miles per hour. This speed probably corresponds to the critical speed for the aerofoil at the extreme tip when working at the corresponding angle of attack. As the velocity is increased the critical speeds of sections nearer the hub are progressively obtained, so that there is considerable lowering of the thrust torque ratio when the speed of 1,800 R. P. M. is reached. (For explanation of the critical speed of propeller aerofoils, see Article by F. W. Caldwell and E. N. Fales in "Automotive Industries" for August 28, 1919.)

A curve showing the horse-power of the propeller at various R. P. M. is drawn in on logarithmic paper in Fig. 8. Adjacent to this curve is drawn a line representing what the curve would have been if the power were proportioned to the cube

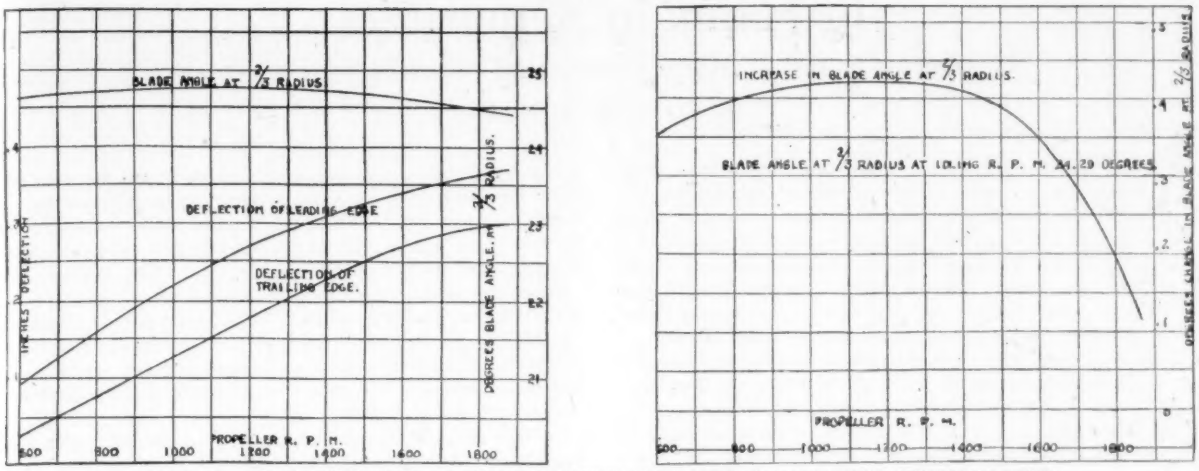


FIG. 11. CHARACTERISTICS OF TYPICAL PROPELLERS FROM McCOOK FIELD WHIRLING TEST

of the R. P. M. It will be noted that the horse-power is not proportional to the cube of the R. P. M.. In view of our present knowledge of propeller aerofoils, it is not to be expected that the horsepower would be proportional to the cube of the R. P. M.

A typical set of deflection readings for a propeller is shown in Fig. 11. Reference to the curve showing the blade angle at various R. P. M. shows that the angle first increases and then decreases as the propeller is speeded up. This is shown in a more pronounced manner in Fig. 12, where the change in blade angle, referred to the original angle, is plotted against R. P. M. We have assumed that the change from an increasing to a decreasing blade angle is the result of a shift in the center of pressure of the aerofoils.

The change in angle of the propeller in motion offers some very valuable data to the designer. While the distortion at a fixed point undoubtedly differs considerably from the amount of distortion encountered in flight, experiments on a series of different blade shapes have enabled us to draw some important conclusions as to the effect of different blade shapes on the distortion. The results have been particularly useful in connection with the stress analysis of propellers.

The actual destructive tests have covered a very wide field. Tests have been made on various types of propellers, such as automatically variable pitch propellers, adjustable pitch propellers, propellers made of steel, composition propellers, various designs of wooden propellers, and various methods of constructing wooden propellers from conventional designs.

In an article of this kind it is obviously impossible to cover with any degree of detail the ground of the experiments which have been carried on. It may be said, however, that about two hundred and fifty tests have been made on this plant for the Army and Navy, and that propeller failures in service have been reduced to an extremely small number. At least two inventions, the Micarta Bakelite propeller and the variable pitch propeller, have been developed to a point where they bid fair to become important factors in the aeronautical industry.

ELECTRIC TRUCK WITH REGENERATIVE BRAKING.

DR. CHARLES P. STEINMETZ has recently announced the development, after a number of years of research, of a light weight electric truck, one of the principal features of which is the method of motor control giving the motor compound characteristics by a storage cell floating on the field circuit.

The result of this method of control is speed maintenance, quick starting, power saving in the beld at large currents and the feature of regeneration both on down grades and on stopping.

The field and armature of the motor revolve in opposite directions, each driving one of the car wheels. In this way motor weight is saved, the differential is eliminated, and the truck is as a result simpler and more compact.

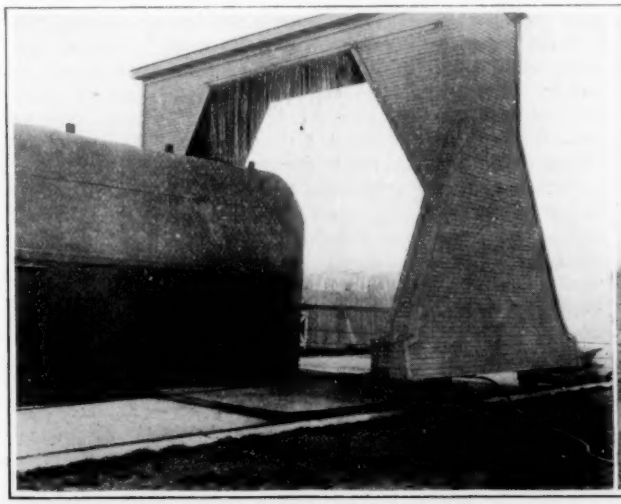


FIG. 12. VIEW OF PROPELLER UNDERGOING WATER SPRAY TEST LOOKING DOWN STREAM

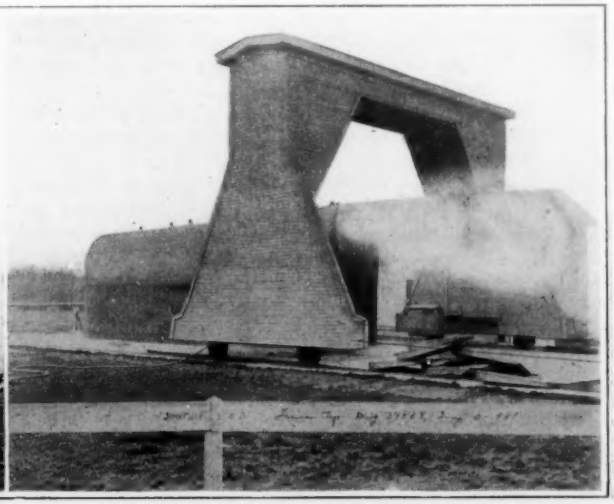


FIG. 13. VIEW OF PROPELLER UNDERGOING WATER SPRAY TEST LOOKING UP STREAM

Invention in Aeronautics*

Is America Going to Attain Commercial Supremacy in the Air?

By Frederick W. Barker

As the nobler sensibilities of mankind have always found expression in words of upward import, and human constructive unrest has employed those language terms which pertain to things and conditions above the earth, it is only natural that inventive endeavor through the ages should have been so largely directed toward solving the problem of flight by man, to which the final touch that changed probability to success was given by the Wright brothers in 1903.

I recall to you the wondrously poetic and masterly review by the Honorable James M. Beck, given before the Aeronautical Society of America on the decennial anniversary of the Wright's success, in which the struggles of inventors through the centuries to conquer the air were described in silver-tongued oratory. This address will I know always be fresh in the minds of our members and needs no traversing.

In our almost immediate times it was Sir Hiram Maxim, brother of a past president of the society, Professor Langley and Octave Chanute who contributed some of the real pioneer work which enabled the Wrights to take their power glider into the air and to control it laterally against falling.

The principles of lift and drift for sustentation of an aerofoil were appreciated and applied before the practical demonstration in 1903 of compensating means for variable pressures which gained the victory and discovered to the world mechanical means for maintaining the stability of a flying machine.

Here then was born the invention of the airplane, involving actual, competent material for a basic patent. Basic in the sense that the principle of balance control was first demonstrated. The means employed—flexible wing portions to be warped in a helicoidal fashion—were not ideal, but they were practical and they served the purpose.

The Wright patent has been the subject of too much discussion by patent experts, and its sustainment by the Appellate Court has apparently so completely closed all controversy that more than mere comment would be out of place.

The particular point in the Wright patent that has always appeared puzzling is, why the broadest claim in the patent was couched in the restricted language employed. The claim reads like this:

"In a flying machine, an airplane having substantially the form of a normally flat rectangle elongated transversely to the line of flight, in combination with means for imparting to the lateral margins of said airplane a movement about an axis lying in the body of the airplane perpendicular to said lateral margins, and thereby moving said lateral margin into different angular relations to the normal plane of the airplane."

The method of expressing the idea of varying the wing surfaces for lateral control could have been better expressed as follows:

"In an airplane, a supporting aerofoil, and movable portions arranged at opposite sides thereof to respectively increase and diminish pressure resistance, for lateral balance."

Then the claim would have been in better shape for judicial endorsement, which the splendor of the Wright brothers' achievement warranted, without requiring to lean upon sympathetic consideration of the court, which to my mind was the determining factor in its favor.

As matters stand however the Wright patent is the foundation patent in the art of aviation with respect to movable wing portions of ailerons, and there is nothing to prevent the present owners of the Wright patent from enjoining other unlicensed users of this balancing feature.

The Wright patent does not cover *any* means of compensating for variable side pressures, and there are not wanting other inventors who have sought and are seeking to devise different means for enabling an airplane to fly with lateral balance. The art is necessarily enriched by such attempts of a more or less practical character.

Since the heavier-than-air machine, as thus far evolved, comprises a supporting aerofoil, longitudinal and lateral control ailerons, and a directional rudder, development will be mainly through refinement of these elements, and in the creation and refinement of the thousand and one accessorial devices which naturally result from intensive work and study.

Other types of flying machines, such as the helicopter and ornithopter still in the womb of invention's laboratory, cannot receive the assistance of engineering ability until they at least assume the condition of fledgelings, to offer some basis for scientific development. But the airplane has today a recognized structure composed of coördinated elements which interact to supply all the necessary functions for controlled flight.

A new art is thus born into the world, having vast potentialities for expansion, now occupying the minds of inventors in all civilized lands, whose interests will grow with each unfolding feature until aviation becomes actually an exact science that shall place its protective mantle over the greatest industry that has ever been known.

America, following her brilliant initiative in blazing the way for flight by man, fell behind other nations in progressive work, while England, France and Italy produced advanced examples of flying machines—though these have been mainly of military types. But the native inventive genius of Americans is again coming to the fore, and it is certain that the next few years will show the most radical improvements to be of American origin.

This therefore seems to be an opportune time to offer a suggestion or two to aeronautical engineers and others as to the part patentable invention is bound to have in bringing about a perfected state of aviation.

From time immemorial we have had vessels that could float on water because the density of that medium permits buoyancy, and the air also was found to give buoyant support since the days of the hot air balloon; but the real conquest of the air came only when a controlled airplane was caused through speed of its movement to pack the air before it sufficiently to convert the tenuous atmosphere into a weight sustaining medium. Even as the child first learns to walk totteringly upright, and gradually with the aid of his intelligence, under practice and with increasing strength, walks firmly and then can run, all with perfect assurance and grace, so will man improve his new winged vehicle to the extent that it will eventually satisfy all his needs of aerial navigation.

Of course it is the internal combustion motor which rendered possible the flying machine, and we have to thank the automobile industry and the engineering profession for the numerous refining influences they brought to the motor and thus gave the airplane its opportunity to come into being. But it must not be overlooked that the automobile motor has also proven the most serious handicap that aviation has had, simply for the reason that we have sought to apply to a new, more arduous duty an instrument that had been perfected along lines suited only to an older and less difficult task.

Invention has still its most important field in the production of a thoroughly reliable aviation power plant, and this will come through designs providing sturdy construction wherein the weight is kept within bounds, with more efficient temperature control, continuous and thorough lubrica-

*Read before the Aeronautical Society of America, January 20, 1920.

tion, an ignition system that can be absolutely depended upon, and propelling means that will develop a maximum of thrust. Patents which improve these and allied features to help the power plant in the delivery of continuous high power output over an extended period will do more than anything else to advance the cause of commercial aviation. This progress will be gradual and tested out at every step. But inventors and aeronautical engineers must get completely away from the intermittent and low duty form of motor which is good enough for the automobile, and strive to meet the sterner conditions of a flight sustaining power plant.

The scope for inventive ingenuity in this field alone is so vast and the reward for success in every detail so sure and generous that its attraction is irresistible and will be responsible in the next few years for innovations which will easily differentiate the aviation motor from the automobile motor.

Invention also will show the way to take off an airplane without a starting run over the surface, and to alight and stop wherever desired. The natural forces to serve these ends are available, and even now are in process of harnessing.

Here and there will stand out some bold concept whose deviser may achieve more fame and receive greater emolument than others, but ancillary devices, marking various stages of development, will result as the contribution of many inventors who attack the problem involved from different points of view.

There was published recently in the Journal of the Patent Office Society a report by J. H. Colwell, one of the principal examiners in the Patent Office, of the more important subjects treated of by inventors, and this report, in so far as it relates to aeronautics, is so succinct and comprehensive that I am introducing Mr. Colwell's account in this paper. It reads thus:

"The importance and the application of heavier-than-air craft to military purposes is obvious and self-evident.

"The attention of the country immediately centered on this new form of vehicle, and it was natural that the minds of experts and inventors were directed to improvements in and devising new forms of aeroplanes, as well as to numerous related auxiliary devices, with the result that the Patent Office was flooded with applications bearing on aeronautical devices.

"There is believed to be no exaggeration in asserting that the advance in the development of heavier-than-air craft made during the past five years would have taken from fifteen to twenty years under normal circumstances; 'Necessity is the mother of invention.'

"In so far as the development of a practical machine is reflected in the Patent Office, no new principle or mode of air-sustained flight appears to have been evolved. The aeroplane of the present day is based on the same principle and involves the general structure as first employed by the Wright brothers in their successful air flight in the first decade of this century. Notwithstanding this, however, there is a wide gap between the air craft of today and that of 1914 as regards the general efficiency, inherent stability, carrying capacity, motive power, controls and radius of action, as well as in various accessories, including instructional and training devices.

"The improvements show a general tendency to widen the range of use by anticipating larger load carrying capacity, necessitating increased engine power, and improved motor construction. Different types of modern planes are now equipped with engines ranging up to over 1,200 h.p., including multiple engine units with reserve power.

"There is no reason to suppose that the limit has been reached, but, on the contrary, the air navigation is still in its infancy.

"Increased power calls for increased strength in frame construction without too great a sacrifice of lightness, as weight is a vital factor. This brought to the fore forms of bracing, struts and trussed wing beams. To overcome excessive wind resistance of exposed parts, which cause a useless waste of power and speed, attention was turned to fairing and stream-lining all such parts, as struts, spars, engine housings, fuel tanks and radiator casings, as well as landing carriage frames. As at high speeds comparatively small areas exert by their wind resistance a greater relative detrimental influence, stream-lining the guy and brace wires has even been resorted to.

"To secure increased strength with the necessary lightness, resort is had to hollow metal tubing, but more generally to various forms of laminated wood framing, as embodied in struts, wing beams and ribs, as well as the fuselage and pilot's car itself. With methods devised and means of uniting and arranging the grain of wood laminate, it is possible to construct a wing rib lighter than one of steel of the same strength. Various materials, as aluminum and other metals, and compressed and treated fibrous structures are constantly being devised, as substitutes for linen in the supporting wings, and also, various substances and compositions commonly termed 'dope,' for treating the wing surfaces.

The hulls and pontoons of hydro-aeroplanes and flying boats are constantly being increased in size and strengthened to make them more seaworthy in withstanding rough water, and the shock of alighting thereon. This has led to the creation of what might be considered a distinct branch in marine ship building, to some extent following the lines of the earlier hydroplane or speed boat. Increased strength necessitates the introduction of longitudinal and tansverse hull framing, providing bulkheads for ballast and other compartments, analogous to that in ship building with variations to resist special strains resulting from the peculiar demands.

"A system of aeroplane construction which is being developed and particularly adapted to large craft, appears on its face, not only interesting, but plausible and practical, provided the location of the weight is not detrimental. Broadly stated, the system comprises a hollow plane merged into the fusilage so that the large trussed wing spars, the engine housings and fuel tanks, as well as the pilot, are enclosed within the lifting surface itself. The center of the plane between the upper and lower walls is deep, while the wings taper to small depths towards the tips. The entire machine, including the pilot's car, is practically a part of the lighting surface, thereby necessitating comparatively few external wind resisting parts.

"Among other devices which are being continually received are detaching means for readily releasing bombs, mail bags and other articles, steering devices and automatic controls, wind pressure vanes for automatically regulating the speed, maintaining a constant angle of incidence and preventing the machine from being pointed dangerously upward, to exceed the critical angle and thus cause stalling, with a resulting fatal tail spin.

"Knock-down aeroplanes for ready transportation and assembling, telephone and telegraph accessories, and wind fans or mills for driving electric generators, and air and fuel pumps have received considerable attention.

"The merits of a heavier-than-air craft capable of hovering in the air, or stopping in flight, and also of descending and rising vertically have been fully appreciated, both for military and other purposes. The advantages of such a machine are obvious; among them is the necessity of only a limited or small area of ground space for landing and launching. Numbers of machines designed to possess these qualifications have appeared, the most common type being the helicopter or horizontally rotating screw propeller for exerting thrust. Some of these have no lifting plane, relying solely on the helicopter thrust, while others propose to use the helicopter in conjunction with the ordinary aeroplane, and so to arrange the power transmission that the tractor or pusher propellers can be cut out and power applied to the helicopter, or both operated simultaneously.

"Although it appears that, as yet, no practical and successful machine of the above type has been evolved, it is by no

means improbable that this problem will be solved in the near future, in view of what has been accomplished and the great strides in development along these lines by keen minded men of mechanical experience.

"In view of the constantly increasing altitude being reached in air navigation, numerous systems are being developed for obviating the ill effects of the highly rarified atmosphere, both on the pilot and in the functioning of the motor. These comprise various arrangements for compressing air, including wind fans, or motors otherwise operated. Some utilize the exhaust of the main engines for driving a turbo-compressor. By this means, a constant supply of air at uniform pressure is received, which is automatically regulated in accordance with elevation."

It will have been noted from the foregoing report that the sphere of invention has already widened out to an extent that admits the thoughtful endeavor of experts in many avenues of research, and proves that the inventive world is surrounding aeronautics with an association of arts, which, while each borrowing from one or more older arts, is itself of special character, and all of these new arts are interrelated through the science of aerodynamics, to whose dominant influence all aeronautical arts must be subservient.

The growth of the automotive industry in the past score of years to its present colossal proportions has undoubtedly robbed thoughtful persons of doubt concerning the possibilities before the flying machine, though still there are timid ones who prefer that others, and not they, should invest money in aviation enterprise, or that others, and not they, should venture to fly. Were all men so shortsighted there would be no progress, but that America does not lack boldness of spirit, alike in its captains of finance and in the masses of its people, to guarantee the adoption of aerial transportation, and the support of worthy aeronautical undertakings, is beyond question.

Though today, to the man in the street, there seems to be a lag in visible production of aircraft in America, that is only the surface view. The surest sign of the times is in the Patent Office, where inventions in the aeronautical arts already surpass in number those of many older arts. With invention rife, the meaning is that demand exists even though that demand is in as intangible form as invention itself. For invention springs from super-mentality, creating something new to satisfy an unprecedented condition.

Vision and courage only are needed in America to enable her to win commercial supremacy in the air—such vision and courage as the warring nations of Europe had in 1914 when they improvised, under fire, different types of aircraft for different military usages. True, expense was a minor consideration then, for the existence of nations was at stake. Now, America's honor is involved, for she is behind other nations in the production of up-to-date passenger and merchandize-carrying machines. This slumbering giant of potential productiveness must be pricked, and perhaps the golden guerdon dangled before it, to rouse it into its instinctive desire to out-distance all others.

The American inventor is doing his part in aeronautics, as he has ever done in other arts and sciences, enriching the world with new thoughts and ideas which need only application to crystallize into further development; and this is actually the epochal period when the judicious investment of money and business endeavor stand to realize the most glorious harvest that has ever been gleaned in industrial fields.

CONTROL AND MEASUREMENT OF ALTITUDE RECORDS.

IT is of great importance that the performance of typical aeroplanes should be accurately known, and that methods of precision should be adopted for determining the actual path of a machine during a test flight. For this purpose Lieut. Robin writing in L'Aérophile of October, 1919, suggests the use of a barograph and a recording thermometer. An explanation is given of the method of reduction of the records, based upon the formula of Laplace, and an illustrative case is worked out.

The barograph is a very simple aneroid type. The pressure gauge consists of a series of thin cylindrical metal boxes, each of which has its base fixed to a spring beneath. Each box is exhausted, and its deformation under external pressure is limited by the spring, so that the deflections are proportional to the atmospheric pressure. A system of amplifying levers and a clockwork recording drum complete the outfit.

The thermometer is of the Fournier type. It consists of a cylindrical reservoir containing a small quantity of light, volatile liquor at its upper closed end. The remainder of the reservoir, together with a communication tube, and a flexible, crescent-shaped tube with one end fixed, are filled with a denser liquid. An amplifying device (and needle moving over a rotating drum) enables the movements of the free end of the flexible tube to be recorded. The movements registered are due to the expansion and contraction of the saturated vapor of the liquid at the top of the reservoir which acts as the thermometer bulb.—Abstracted by *The Technical Review.*

STEREOPHOTOGRAPHY FROM AN AEROPLANE.

OBSERVED from a sufficient altitude, the ground appears like a two-dimensional map, and nearly all plastic effects are lost. Stereophotographs, however, give us good ideas of level distribution, and, with the help of the stereo-comparator accurate measurement of height can in certain cases be obtained. These photographs are thus of the greatest utility for surveying purposes.

Several methods for obtaining stereophotographs are given by W. Klemperer, in *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, October 15, 1919. The easiest way is to use two aeroplanes flying at the same height on the same course or on a parallel course. By photographing one aeroplane from the other on a special camera, the distance between the aeroplanes can be determined.

Besides this "distance" camera, both aeroplanes are equipped with a stereocamera proper, whose optic axis is suitably inclined. The inclination will depend on the focal length of the camera, the altitude of flight and the distance between the planes. This inclination will also settle the degree of plasticity obtained.

In the case of the aeroplanes steering a parallel course, the camera axis is inclined across the direction of flight so that a stretch of country lying midway between the two aeroplanes is photographed from two points of view. In case of the same course being steered, the leading machine has its camera inclined to the rear and the following machine to the front, so that the same stretch of country is again photographed from both machines. If only one aeroplane is available, two flights are required.—Abstracted by *The Technical Review.*

BOY MECHANICS FOR THE BRITISH AIR FORCE.

THE Air Ministry has recently instituted a new scheme to secure the entry of well-educated boys for training as skilled craftsmen.

Under this scheme, boys will be entered between the ages of 15 and 16 years for a period of ten years' color service in the Reserve. During the first three years they will undergo a course of educational and workshop training, graduating them to the rank of Leading Aircraftsmen in one or other of the skilled trades.

Those who show most promise during their training will be chosen for an additional six months' course of higher instruction, being promoted at once to the rank of Corporal. From among these, some may be selected for the grant of a commission, and will proceed to the Cadet College for training as flying officers.—Abstracted from *Aerial Age Weekly.*

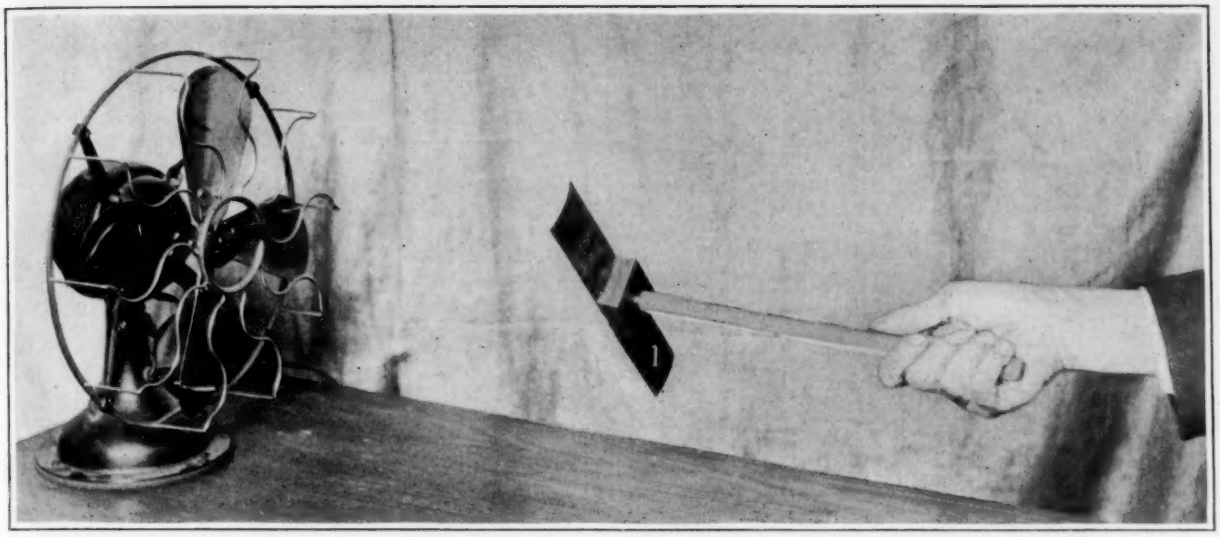


FIG. 1. WHEEL WITHOUT TWIST OR WEATHER ANGLE WHICH WILL TURN IN THE BLAST OF AN ELECTRIC FAN

Paradoxical Windwheels and Soaring Birds

Rotary Thrust Produced Without Weather Angle

By Thomas O. Perry

THOSE who are familiar with windwheels know, or think they know, that the weather angle of the wings, or their inclination with the plane of motion, is a necessary feature for propulsion by the wind, and that the wheel must turn only in one direction according to the angle of weather.

In Fig. 2 are shown photographic prints of five small windwheels which, when held facing the breeze from an electric fan, were wind driven clockwise or anti-clockwise without any alteration either in construction, position or other conditions. Three of these wheels apparently turned one way as rapidly as in the reverse direction, the slight difference evidently being due to some rotation of the blast from the fan in the direction of fan revolution. This difference was eliminated when the blast was directed through a tunnel with thin longitudinal partitions. Our illustrations omit the tunnel which was used, but is not necessary except for refinement in exact tests.

Those who are skeptically inclined are advised to first try forms No. 1 and No. 2, as these two forms are very easily made and as easily managed. We have shown No. 1 with a wooden hub joining opposite wings separately attached, but the wings can as well be made of one piece of thin metal of uniform section from end to end without twist or weather angle throughout its length. Any kind of hub will do, and the exact curvature of the wings is not important. We made the camber about 1 in 14, width of wing 1¾ inches and length 10½ inches. The electric fan used was 12 inches in diameter, had a speed of 1,800 r.p.m. and was placed from 15 to 20 inches away from the windwheel. The average speed of the windwheel in either direction was about 1,390 r.p.m. This wheel had to be started by giving it an initiatory whirl with the fingers, though it would turn slowly of its own accord in a *direction contrary to the fan's motion*, in which respect this particular wheel was peculiar.

Wheel No. 2 was made of white pine and received the blast squarely against its flat face. The back was rounded from 3/16 inches thick along its center line to thin edges about 1/32 inch thick along the sides. To make this wheel it is only necessary to take a straight piece of wood 10½ inches long, 1¾ inches wide, 3/16 inch thick and round over one side from end to end. Any kind of hub will do, or no hub. This wheel is started very easily with the fingers and runs in either direction at about 1,650 r.p.m. On account of its lightness, the acceleration after starting is very rapid.

Wheels No. 1 and No. 2 responded so vigorously to the impulse of the wind after being started in either direction, that we were tempted to try another wheel made precisely like No. 1, except that the two wings were given a small weather angle of about 3 degrees after the manner of ordinary windwheels. This wheel, No.

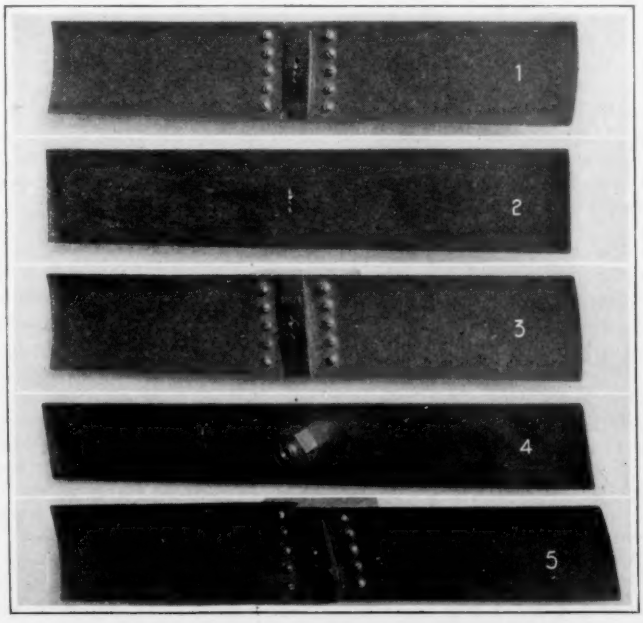


FIG. 2. WINDWHEELS USED IN THE TESTS

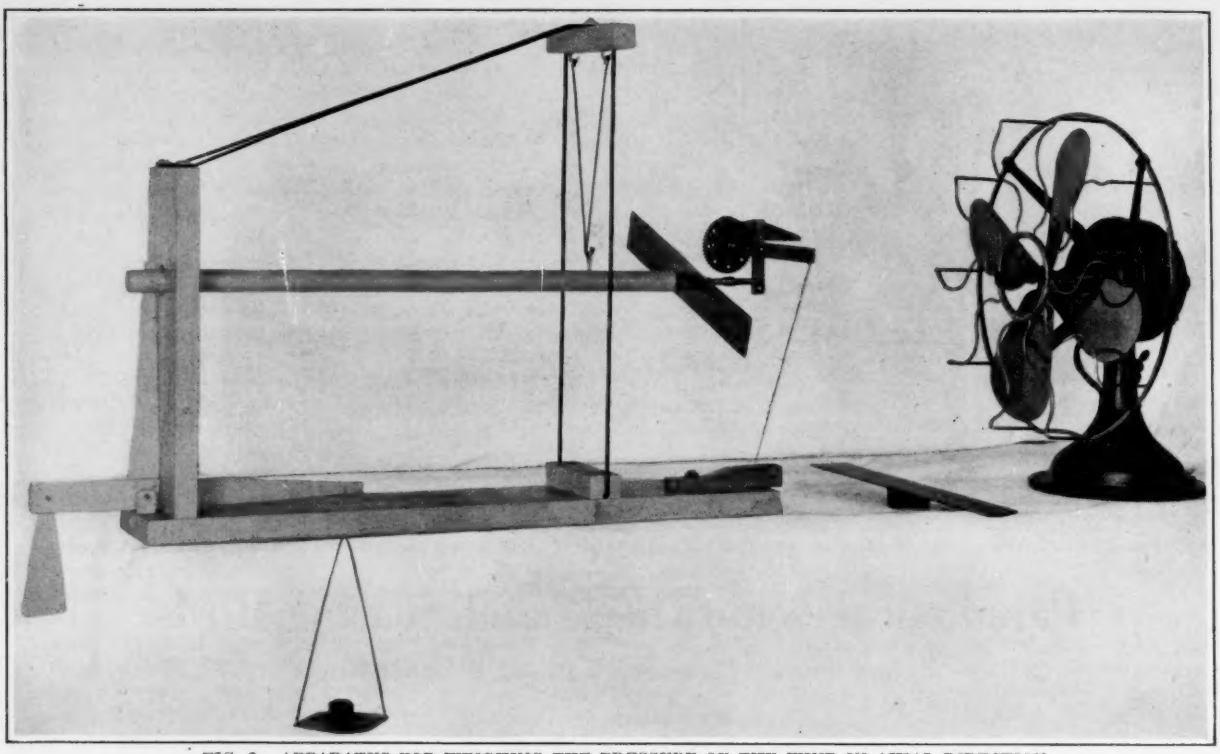


FIG. 3. APPARATUS FOR WEIGHING THE PRESSURE OF THE WIND IN AXIAL DIRECTION

3, would readily start itself and run in one direction just as any one would expect, making about 1,560 r.p.m. But, if given a vigorous push to start it in the opposite direction, it would run and maintain about 960 r.p.m. *against natural inclination.*

The fact that wheel No. 3 with considerable weather angle could be made to run backward against inclination, as well as the fact that wheels No. 1 and No. 2 ran equally well in either direction they were started, was at first supposed to be due entirely to the fact that these three wheels had at least one side made with transverse curvature. It was with the expectation of confirming this supposition that wheel No. 4 was made with both face planes parallel to each other. No. 4 was nothing more than a plain strip of hard and smooth sheet brass about 1/16 of an inch thick, 1½ inches wide and 10½ inches long fitted with a small hub at the center. Contrary to expectation, this wheel, too, maintained a speed of 1,030 r.p.m. after receiving a good start in either direction. It had to be started at much higher speed than any of the others by winding a string around the hub. It also had to be nicely balanced. Slightly rounding the sharp corners of the edges improved its performance.

Wheel No. 5 was the same as No. 3 except that the weather angle was increased to 8°, making it correspond more closely to the angle of ordinary windwheels. This wheel would not run backwards, and behaved according to expectation except in one particular. It made about 1,860 r.p.m. in a left-hand direction. Wheel No. 6 was the same as No. 5 in all reversed. It ran at about the same speed when used with the tunnel, always running in a right-hand direction. These two wheels would make about 690 r.p.m. with their convex surfaces presented to the breeze. None of the wheels which ran indifferently in either direction would really *run*, with its convex back presented to the wind. No. 4 was the only one that ran with any speed with either side exposed to the wind. This too was the only wheel with both sides plain and exactly alike.

The one particular in which wheels No. 5 and No. 6 appeared paradoxical in performance was in the fact that when running freely without any applied load, it was found that the wind pressure against their wings was more than three times as great as when they were clamped to their axles so as to remain stationary. Fig. 3 shows an apparatus designed to weigh the pressure of the wind in an axial direction by means of weights placed in the pan hung from the horizontal arm of the balanced T lever. The pressure against the wings increased with increase of speed of revolution until at the maximum the pressure was greater than that on a solid disk of the same diameter as the wheel.

In measuring the power of the windwheels with a dynamometer we have invariably found that speed of revolution was reduced with every increase of load applied with a brake, and that the torsional effort of the wheel as shown by the dynamometer was progressively reduced as the speed of revolution increased. This, too, accords well with common sense. Nevertheless, the facts are as stated in the preceding paragraph. Also wheels Nos. 1, 2 and 3 received nearly as great wind pressure at full speed as Nos. 5 and 6, and fully as great, or greater, than the pressure against a solid disk of the same diameter.

These experiments serve to throw some light on certain puzzling facts which force themselves on the attention of those who observe closely the flight of soaring birds as they rapidly float along on rigid wings without any apparent means of propulsion. Certain authorities have asserted that propulsion in soaring flight must be due to a negative inclination of the wings sustained by rising currents of air. We believe that both of these professed observations are products of the imagination rather than of actual vision, though an equivalent must be substituted for the supposed rising currents.

If rising currents of air do really account for the possibility of soaring flight, it is not necessary to assume that the wings must have negative angles; since these experiments show that wings of windwheels (Nos. 1 and 2), without any weather angle are propelled by wind whose direction is at right angles to wing motion after sufficient headway has first been attained. In the same way birds must somehow get well started before they can soar. Mr. Chanute places the

minimum soaring flight of birds at about seventeen miles per hour.

Eiffel has shown that an airplane wing driven against the air, or exposed to wind impinging in a direction parallel with the chord of a wing having its concave surface underneath (that is, without weather angle), experiences a very decided upward thrust and that a negative angle of three degrees does not entirely neutralize the lift. Our experiments show that a windwheel whose wings have a weather angle of three degrees will run backwards after being sufficiently started in the reverse direction. From this it follows that a bird's wings receive upward thrust in the same way by reason of their forward motion. We also know that vibrations in the air, or air waves, which crowd against the wing incessantly from every direction, all act more strongly against the under concave surface than against the upper surface which is convex.

The difference of thrust due to air vibrations against the two surfaces of opposite curvature is not very great unless the wing is traveling at considerable speed. The rapid motion multiplies the differences of opposite thrusts and produces an aggregate upward thrust sufficient to sustain the bird without supposing the necessity of rising currents of air. Prof. Langley has partially explained the effect of air waves on the wings of soaring birds in his treatise dealing with The Internal Work of the Wind, though he accounts for the action of horizontal impulses only, and it is not necessary to suppose that the bird instinctively adjusts its wings fore and aft, in the light of Eiffel's experiments. It is clear that horizontal impulses give a resultant lift whhether impinging from the front or from the rear against horizontal crescent shaped wings.

Rising air currents more generally prevail over heated land surfaces. But what goes up must come down, and the cold southern seas must experience an excess of descending air currents. Yet there is the home of the most noted of soaring birds, the Albatross, a bird that habitually soars, and evidently does not have to hunt out exceptional streaks of rising currents or follow devious courses for the sake of their assistance.

How Insects Steer Themselves While Flying*

"Weight Steering" and "Pressure Steering"

By Dr. F. Stellwaag, Privat Dozent at the University of Erlangen

THE positions of a hovering body in space is dependent upon the situation of the center of gravity on the one hand and upon its surface on the other. When any flying animal, therefore, wishes to alter its direction while flying it must alter either the location of the center of gravity or else the surface of its body. It both cases we are concerned with steering arrangements, but the manner of functioning is different in the main. "Weight steering," if I may so express myself, operates by means of a change of equilibrium due to a shift of the center of gravity. Thus it is to be supposed that the body of an insect is more heavily loaded on one side or the other when the abdomen is curved towards the right or towards the left. Consequently the body must swerve in a direction which corresponds to the resultant between the direction of the force of gravity and the original forward moving direction of the wings. This sort of steering is in use in many airships by means of a sliding weight. In such cases it is, of course, the weight alone which plays a decisive part.

Just as it is possible to think of the weight of a body as being united at one definite point, *i. e.* the center of gravity, in the same way in the case of a body which is moving forward and which is therefore subject to the resistance of the air, we can think of a single point, *i. e.* the center of pressure, as representing the force of the air pressure against the surfaces involved. The position of the center of pressure changes as soon as the surfaces of attack of the body of air in motion are altered. If this alteration is one-sided a change of direction will be produced. This "pressure steering" never operates through weight and may be even regarded theoretically as being without weight. The more rapid the motion of the moving body the greater the amount of work done by this pressure steering, since it operates by the capacity for work of the secondarily occasioned air pressure. The steering of water craft and air craft comes under this head of pressure steering almost without exception. It may be termed extra-directive steering in contrast to intro-directive or weight steering. It is precisely this difference which makes it possible to understand various phenomena concerned in the manner in which various animals move and to throw light upon various problems which are generally very obscurely treated in text books on biology.

We are chiefly indebted for such knowledge as we possess concerning the steering capacity or insects to Jousset de Bellesme.[1] His experiments with insects of all kinds led him to believe that the direction during flight is determined by the position of the head and thorax, *i. e.* of those parts of the body which penetrate the air; in his opinion it depends upon the center of gravity and upon the position of the axis of support, both of which are movable. In most cases it is the center of gravity alone which is responsible for an alteration of position. In only a few insects do the functions of motion and direction coincide, those which possess direct flying muscles and can therefore move the wings separately, like the *Aeschna*. However the long and movable abdomen plays a part in modifications of the movement, as can be plainly seen in the Agrionids. The same thing may be considered to be true of the butterflies whose wing movements resemble those of birds.

In the Hymenoptera the wings serve merely to produce forward motion, the abdomen is very movable and is thus capable of altering the center of gravity and therewith the direction of movement by taking different positions. If the insect is deprived of this freedom of motion in the abdomen, it appears to be still able to fly but no longer to steer itself. In the *Megachile*, *Polistes* and other Hymenoptera, the legs also take part in the shifting of the center of gravity. In the Orthoptera the abdomen is only slightly movable; the hind legs might here be concerned as an organ of direction were they not specialized for the function of jumping. They are poorly adapted for steering and as a matter of fact the Acridia and Locustidae are but ill able to guide themselves.

In the insects just mentioned both wings on each side are designed for the purpose of forward movement. In the insects now to be treated of, functional adaptation has created organs suited for definite purposes. One pair of wings is used

*Translated from the *Biologisches Centralblatt* (Leipzig), January 20, 1916.

[1]Bellesme, Jousset de. (a) Recherches Exper. sur la fonction d. balanciers chez les insectes dipt. (Exper. Nesearches Concerning the Function of Balancers in Dipterous Insects). Paris, 1878. (b) Sur une fonc. de direct. d. le vol des insectes. (Concerning a Function of Direction in the Flight of Insects). C.I. Ac. Fr., 1879 b. vol. lxxxix.

for forward movement and the other for the alteration of the direction. Since in the beetles the abdomen is closely united to the metathorax, it possesses but slight freedom of motion. However, there is no need for it to be movable since the wing covers or elytra have assumed the function of steering. During the active flight they are lifted above the thorax and are thus placed above the center of gravity in such a manner that even very slight variations of their position serve to influence the position of the latter. If the wing covers are removed the insect is no longer able to direct its flight. This shifting of the center of gravity has been demonstrated with precision by Plateau.[2] Only those insects belonging to a small group, the *Cetoniidae* fly with covered wings, an interesting circumstance since the wing cover in this case acts upon the axis of sustentation which forms a *transition* to the state of complete differentiation in the *Vittera.*

Among these the capacity for steering is best developed. Only one pair of wings is employed for forward motion. But slight mobility is possessed by the abdomen and thus the only organ for determining direction is the "balancer" on each side. When this organ is amputated the center of gravity is shifted too far forward and this so affects the power of flight that the insect falls to the ground. If now, however, a small weight is attached to the abdomen so as to shift the center of gravity the proper distance to the rear, the insect is capable of flying in any direction in spite of the loss of its balancer.

According to the view of Jousset de Bellesme (just quoted) insects direct their flight, therefore, entirely by weight steering. In this he agrees with Plateau, Bert,[3] and other authorities. This opinion is contradicted, however, by the information now available. I have myself proved by anatomical-physiological and experimental methods that the wing covers of beetles by no means exercise the rôle hitherto ascribed to them.[4] They operate by pressure steering, or still better as stabilizing planes. In the balancers of the Diptera, however, a complex nervous apparatus has been detected by means of which flies perceive variations of equilibrium. That in spite of this they might influence the direction of the insect's flight as a weight rudder, was held indeed twenty-five years ago by Weinland.[5] But this view finds but little support at present; it certainly seems doubtful at least that an organ so light in weight is capable of producing an alteration in the direction of flight. This would be possible only in case the elytra lay in the same direction as the obliquely situated line of gravity. Various measurements made by me, however, proved clearly that the center of gravity in the different kinds lies behind the roots of the elytra, and that, furthermore, it is shifted still further to the rear after the filling of the intestine or the increase in size of the gonads.

Amans[6] has recently expressed an opinion contrary to that of Bellesme. According ot him insects steer by means of pressure. He calls special attention to the wave like form of the part of the body which is presented to the current of air during the act of flight. As he points out the profile of this part of the body forms a "line of double curvature." It is most marked in form in the Ichneumonidae in which the abdomen is shaped like a sickle. Within certain limits this wave form is of great advantage to the insect during the act of flight from a dynamic point of view; by reason of the fact that its curvature can be varied by the motion of the abdomen it operates as a pressure rudder. The abnormal curvature in the Ichneumonidae would be a hindrance except that we are here concerned with insects which fly very rapidly. For this reason, however, the air pressure is very slight and this has the effect of causing the body to take a horizontal position during flight. In this case, therefore, the abdomen pays the same extra-directive rôle that is exerted by the outspread and downward pressed tail-fan of many birds. Thus Amans, though starting from the same premises as Bellesme, comes to directly contrary conclusions, which appear to me to possess a greater degree of probability. However, in my opinion the problem of the steering capacity of insects deserves renewed and thorough examination.

Serious difficulties attend such an experimental investigation. It is not always possible to remove parts of the body of an insect without injuring the organism. . . . Furthermore, a decrease in the capacity for movement seldom attains the desired object, since such a decrease . . . is apt to affect the steering. For this reason I have made use of entirely different methods.

Anyone who has watched insects closely during their flight knows that they display extraordinary skill in steering in every direction and often deviate instantly from the original path. In case the steering be accomplished by the legs and abdomen in a manner similar to that attained by manipulation of the bow or stern rudder in the case of air and water craft then presumably the greater the skill with which the insect changes its direction the more definite the required alteration in the steering organ. However, I was never able to perceive by direct observation any distinct alteration of the position of the legs and abdomen for the purpose of steering. At first I ascribed this to the inherent difficulty of following with the eye the swift movements of the creature at the decisive moment; however, I obtained a welcome subject of study in the *Libellae.* In cloudy weather or at sunrise and sunset the motions of these insects are feebler than usual and as a result the change of position in the legs and abdomen can be readily followed. The *Libella* (dragon fly) readily steers itself forward, backward, or sidewise without moving its long abdomen for an instant, although the latter is admirably adapted for a rudder. In a swift flight, particularly, for example, when the insect is rapidly descending, the abdomen alters its position. But even in this case it does not alter the direction of flight, but is passively curved, on the contrary, after the insect has taken its new direction.

These observations, I believe, to be entirely trustworthy in spite of the contrary views of many authorities; but they are not yet entirely conclusive since they are subjective in character and are confined to a few favorable examples. In order to attain objective certainty likewise, I made use of a simple arrangement. When parallel rays fall on a body in a vertical direction the body casts a sharply defined shadow of full size upon a surface which is likewise vertically placed. . . . By this method I obtained, of course, only silhouettes, but these presented images of a character which a camera cannot furnish since the latter gives a sharply defined image only at a certain definite distance and an image, moreover, which is usually reduced in size, and since, furthermore, the swiftness of the flight prevents a sufficient time of exposure.

After many failures and after overcoming very serious difficulties I have succeeded in obtaining during the last few years a series of views of different insects by means of light falling through a shuttered slit. In no case have I been able to observe a change of position in the abdomen during the alteration of the direction.

I obtained the same results experimentally. According to their histological structure the elytra are to be regarded as sensory organs of equilibrium. Each passive movement

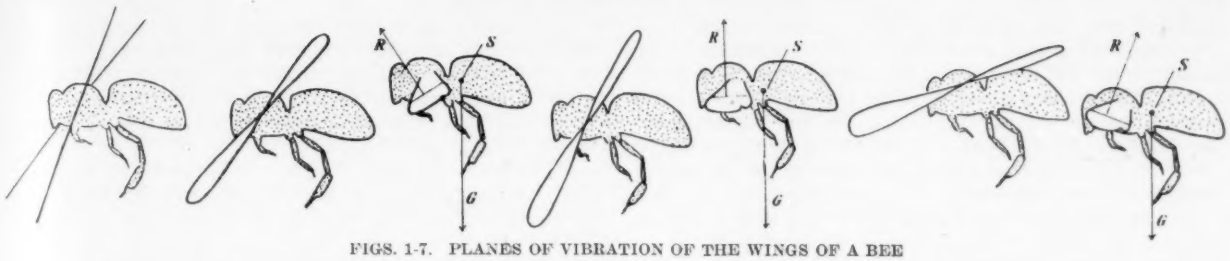
[2]Plateau, f. Recherches exper. sur la position du centre de gravité chez les insectes (Experimental Researches Concerning the Center of Gravity in Insects). Arch. d. sc. phys. et Nat. New Period, vol. xliii, 1872.

[3]Bert, Paul. Notes divers sur la locomotion chez plus. expec. anim. (Some Notes Upon Locomotion in Various Species of Animals.) Mem. of the Soc. of Phys. and Nat. Sc. of Bordeaux, Paris, 1866.

[4]Stellwaag, F. Der Flugapp. d. Lamellicorm (The Flying Apparatus of the Lamellcornia). Zts. f. wiss. Zoöl., vol. cxiii, 1914.

[5]Weinland, E. Ueber die Schwinger d. Dipteren (Concerning the Balancers of the Piptera) Zts. f. wiss. Zoöl., vol. li, 1890.

[6]Amans. (a) Géom. descript. et compar. des ailes rigides. (Descriptive and Comparative Geometry of Rigid Wings). Fr. Assoc. for the Advancement of the Sciences, Congress of Ajaccio, 1901. (b) Sur les lignes à double courb. dans locomo. animale: applications indus. (Concerning Lines of Double Curvature in Animal Locomotion: Indus. Applications.) Reports of the V. Internat. Zoölog. Congress. Nachtrag. (c) En planant (On Hovering); Causeries d' aviation (Talks on Aviation).



FIGS. 1-7. PLANES OF VIBRATION OF THE WINGS OF A BEE

Fig. 1. The different planes of vibration of the wings on each side of a bee when steering. The vibration of the wing is stronger on the right side of the animal than on the left and causes a swerving towards the right. Figs. 2-7 show that the planes of vibration of the wings (in the form of the figure 8) and their positions vary according as they have a forward motion (Figs. 2 and 3), a hovering flight (Figs. 4 and 5) or a backward flight (Figs. 6 and 7). G = direction of gravity; R = resultant of the forces acting upon the wing while beating; S = center of gravity.

of the balancer in a definite plane of space brings to the exterior the termination of a definite group of papillae at its base and orients the body not only with respect to direction but also with respect to the rapidity of flight. But since, as Baunack[1] points out, the function of all organs of equilibrium consists "in so influencing the locomoter organs that a definite position of the body results from their regulatory movements" the fly must react when altering its position with such parts of the body as play a decisive part in the alteration of direction. The more skilfully and the more frequently the insect repeats the steering operation in a free flight, the more clearly marked the reaction. I have already remarked that the wing coverings are not to be regarded as weight rudders. On the other hand, neither are they capable of functioning as a pressure rudder, since they are placed behind the axilla of the fore wings where the path of the beat of the wings is slightest and since they vibrate in the same direction and with the same rhythm as the fore wings. Furthermore, they are covered with the *Squamula thoracalis* as in the *Tabanidae*, *Syrphidae* and *Muscidae*. There are few parts of the body, in fact, which are so well shielded from air currents during the act of flight as the elytra. According to the prevailing view therefore, only the legs and abdomen can function as a rudder.

In my experiments I made use of specimens of the three above-mentioned families of Diptera which not only belong to the best flyers among the Diptera but even among those of flying animals of all sorts, steering themselves with surprising skill and certainty and likewise being extremely adept at sudden descents or what may be called pouncing flights. I grasped them by the thorax by means of a pair of nippers. As soon as the insect began to beat its wings I placed it in different positions so that it now lay on one side, now upon its back, or held a position at a varying angle wth respect to a horizontal line. The abdomen constantly remained motionless in the longitudinal axis of the insect. It was noticeable that the little creature constantly attempted to clasp the nippers. I prevented this by grasping the abdomen with the implement. This made it possible also to observe the positions of the legs. These were entirely voluntary and their alterations of positions could not be regarded as compensation movements with respect to the altered position of equilibrium. I also conducted similar tests concerning the position of the legs, with wasps, bees, bumble-bees, sphinx moths and the *Aeschna grandis* L., always with the same results.

All these observations justify us in concluding that the views of Beiesme and Amans are incorrect. Insects employ neither the legs nor the abdomen as a rudder.

Before I began my experiments with the nippers I made a preliminary test (of imperfect character) by piercing the thorax of the insects examined with an extremely long fine needle. Thereupon it frequently happened, especially in the case of the Diptera, that the insect turned with increasing speed to the right or the left side, so that it soon began to revolve around the needle. These movements took place without altering the position of the extremities or of the abdomen and the thought was suggested that it is the wings which accomplish the steering action.

The manner in which the wings of insects move has been studied by Marey[2] by means of very clever experiments. He has thus discovered that the movements on each side of the body are always entirely synchronous. Thus, the number of beats of the right wing in a given time always agrees perfectly with that of the left wing. This can be very beautifully demonstrated; on pressing the back of the thorax of an insect that has just been killed, both wings at once rise simpultaneously. If one wing be moved without otherwise touching the tergum the wing on the other side makes identical or similar movements. . . . The fact of this synchronism induced Bellesme, as he expressly states, to seek for some steering device outside of the flying apparatus.

Since the experiments described above obliged me to believe that the insect steers by means of its wings, I continued my experiments along this line. I varied the position of the body during the movements of the wings, as in the previous case, and proved that the insect revolved now in the same direction as the hand of a watch and now in the reverse direction, according as I rotated the little creature about its longitudinal axis, which furnishes a proof to begin with that disturbances of the equilibrium of the body are compensated by means of wing movements. Rotations of the body took place, however, when the needle was held stationary in a vertical position. It was evident that the insects experimented upon endeavored in this manner to escape from their uncomfortable position, *i. e.* they tried to steer themselves.

I was able to determine the manner in which insects rotate about the needle by grasping them with the nippers and gently inclining them in different directions with regards to space. Thus the plane in which each wing vibrates was altered. The variatons from each other of the planes of vibration can be best observed from the side, as shown in Fig. 1. In order to make these variations perceptible in a front view, it is only necessary to gild the wings as Marey suggests and allow a beam of light to fall upon them in a definite direction. In this case it often happens that one wing appears dark while the other reflects the light to the eye of the observer.

In many cases the insect not only alters the plane of vibration but also the amplitude of vibration of one wing so that the wing-beats on the two sides of the body differ in extent. These phenomena, however, do not contradict the fact described above of the perfect synchronism of the wings. A person seated in a row boat is readily able to vary the manner of the oar beats on the two sides independently provided only the rudder is moved at the same time. The experiments with *Diptera* and with the *Sphinx pinastri L.* proved that it is possible for the amplitude of vibration of one wing to be

[1] Baunacke. Zur Frage der Statocystenfunktion. (Concerning the Problem of the Function of the Statocyst). Biolog. Centralbl., vol. xxxii, 1913.

[2] Marey. Mém. sur le vol des insectes et des oiseaux (Memoir Concerning the Flight of Insects and Birds). Ann. des Sciences nat. Sér. 5, Zoöl., vol. xii, 1869.

constantly decreased until the wing is entirely at rest while the other wing continues to vibrate. Such alterations in the amplitude of vibrations have also been observed by Boss[9] as shown in his moving pictures of flying insects. He has expressed the view that they are of importance with respect to the steering, the stabilization, and the rapidity of forward movement of the animal. But they not only play a definite rôle but likewise make possible the alteration of the direction of the wing-beat, and also facilitate steering, since the flying apparatus of insects is likewise their steering apparatus, as I believe I have sufficiently proved.

However, it is necessary to go somewhat further to explain theoretically the phenomena of steering.

During rest the wing of an insect usually presents a flat surface. So long however as a surface is uniformly even it is unable to function as a flying surface; for when it beats downward the particles of air are compressed and at once exert, since they immediately seek to return to their original position, an opposite pressure upon the under side which may be designated as anti-parallel to the original direction of pressure, and this would only be increased by the increased expenditure of energy on the part of the insect. However, an insect's wing not only exerts a lifting power but also at the same time a forward impulse, and this occurs, to begin with, by means of the varying elasticity of the wing surface. The *costa*, *subcosta* and *radius*, in the different varieties, stiffen the forward edge, either separately or unitedly, so that this edge is able to split the air like the blade of a knife. But the surface lying behind it increasingly yields the farther it lies from the aforesaid front edge, as can be plainly observed in the wing of a beetle, in which the strength of the veins which support the membrane plainly decreases. The case is analogous in insects in which the hind wings are reduced in size and therefore less powerful than the fore wings, as, for example, in the Hymenoptera and in many Lepidoptera. In order to make a physiologically uniform and effective wing surface the hind wing must be united to the forward wing. This is accomplished in Hymenoptera by means of a little hook and in the Lepidoptera by the clinging brush at the axilla of the wing. The chief value of this arrangement does not consist, therefore, in uniting the rear wing to the forward wing so that it can share the wing movement nor in increasing the beating surface of the wing, but rather in providing the fore wing with a soft or flexible rear edge. During the act of flight consequently the wing constantly attains a weak-formed diagonal. The particles of air struck and compressed by it at once seek to return to their original position and are forced to flow off to the rear beneath the soft rear edge of the wing. In doing this they exert a forward pressure upon the wing by means of which the entire body receives a more or less powerful forward impulse. The form of the wing surface and its physical structure, in connection with the rotation, is therefore an indispensable prerequisite condition for flight. The dammed up air formed beneath the downward beating wing creates on the underside of the wing a pressure which constantly acts in a perpendicular direction to the various portions of the surface. Since the whole surface is curved through the lifting of the rear edge, the chief resultant of the different parallelograms of force does not lie in a perpendicular direction to it, but is somewhat inclined towards the forward edge (Figs. 3, 5, 7, *R*). The force of gravity drawing the body downwards works against the upward impulse.

So long as the wing of the insect is large enough to bear the weight of the body and move forward as in the case of the Libellae it is not forced while beating its wings to make a special alteration of position. If, however the wing is too small in proportion to the body it is obliged to execute rapid and complicated rotary movements (cf. Stellwaag[10]) in order that the rigid forward edge may first penetrate the air and occasion a vigorous downward flow of the particles of air beneath the rear edge. What an amazing amount of energy is expended by the wings when they maintain the elasticity of their rear edges by sharp rotation, is shown in extreme form by the Diptera.

If the insect is merely seeking to go forward it must create for itself a strong impetus. It then so places its wings (as shown in Figs. 2 and 3), that the resultant of the forces is strongly inclined towards the direction of gravity (in Figs. 2 to 7 the direction of the resultant represents an average value, for the wing rotates a little bit as mentioned above when it beats downward). In the hovering flight which is especially preferred by the Syrphidae, the vibration plane of the wing is so inclined towards the horizontal (Figs. 4 and 5) that the resultant coincides with the perpendicular direction. Hence the forward impetus is lacking while the upward force and the force of gravity are in equilibrium. In this position a vertical flight upward is possible when the upward impetus is augmented by rapid wing beats. If the resultant tends towards the perpendicular a movement of the body backwards ensues (Figs. 6 and 7).

In all these cases the wings on both sides beat synchronously—with the same amplitude and in the same plane of vibration—and the body retains the original direction. But if one wing is rotated upward in such a manner that it employs more of the upward impulse than of the forward impulse, there takes place a wavering or rotation about that side of the body which generates the lesser amount of forward impulse (in Fig. 1 this is the right side of the insect). However it is also possible for the amplitude of the wing beat on one side of the body to decrease even to the point of entirely ceasing. The consequence of this is that the body inclines towards this side; it will not fall to the ground since the wings of the other side still carry it forward but it will instantly deviate from the former direction. Through the fact that insects can thus make other movements upon each side, they are able to attain a quite surprising degree of facility in the alteration of direction by a skilful combination of the various wing beats. In Figs. 8 and 9, I have represented the paths of flight pursued by a honey bee and a fly (*Eristalis tenax*) . . . the path is composed of various kinds of movements, now a section of a circle is described in which the head goes first in the direction of the movement and now the insect rapidly turns aside from the original direction without altering the position of the body with respect to space. It is

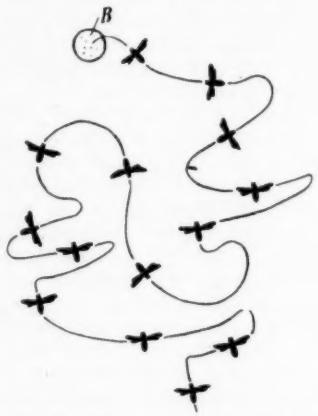


FIG. 8. PATH OF FLIGHT OF A HONEY BEE SHOWN IN THE ACT OF LIGHTING UPON A FLOWER BLOSSOM (B)

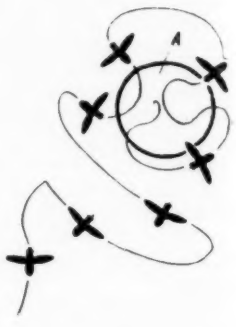


FIG. 9. PATH OF FLIGHT OF AN *ERISTALIS TENAX* WHICH IS FLYING TOWARDS AN ASTER BLOSSOM (A)

[9]Boss, Vergl. Untersuch, ueber die Flugwerkz. d. Insekt. (Comparative Studies of the Flying Apparatus of Insects.) Section 2, Verh. d. deutsch. Zoöl. Gesellsch. Collection 24, 1914.

[10]Stellwaag, F. (a) Bau u. Mech. d. Flugapp. d. Biene. (Structure and Mechanism of the Flying Apparatus of Bees.) Zts. f. wiss. Zoöl., vol. xcv, 1910.

also possible for rotary movements around the point of the abdomen or around the head end of the body to take place. I have observed similar steering movements in numerous other Diptera, in Hymenoptera and also in night moths. The butterflies that fly by day are less skillful. On the other hand their so-called "creased" path of flight can undoubtedly be traced to the imperfect synchronism of the two wings. Especial conditions mark the flight of beetles. Forward movement in a straight line appears to give them but little difficulty. On the other hand they find steering to one side made difficult by the fact that the wing covers obstruct the current of air. For this reason beetles tumble towards the left and right as can be readily observed.

When we compare various insects with respect to their steering capacity we are led to conclude that skill in flying and skill in steering are closely connected, whereas skill in flying and the form of the body do not exhibit such a close connection. The greater the capacity for flight the better able the insect is to steer. Since however capacity for flight depends upon the specialization of the motor apparatus and especially of the axilla of the wings, it is possible to divine the degree of capacity for steering from the morphological nature of the thorax and especially of the axilla of the wings. This fact is of great importance with respect to the anatomical-physiological analysis of the flying apparatus of insects. Many elements of the axilla probably play a part in active steering, and one or another muscle may be brought into service so that its function may be judged from this standpoint.

The problem of steering in insects is closely connected with the question as to how equilibrium is maintained during flight. Among the great number of flying insects only a disappearing few possess static organs. Thus far they have been found only among the Diptera in the *Chermes* and *Phylloxera*. This is the more remarkable since it is just in such excellent flyers that the maintenance of equilibrium must be of the greatest importance. Bethe[11] was of opinion, therefore, that in all insects which possess no static sensory organs the position of equilibrium is maintained mechanically. His experiments are of interest here only in so far as they concern flying animals.

Bethe's methods consisted in first stupefying or killing the animal with chloroform and then allowing it to fall, with the wings arranged in characteristic positions, either freely through a space or else within large wide cylinders. No matter what position the animal was in at the beginning of the experiment it always assumed the abdominal position during the fall and retained it till it reached the ground. "That the form of the animal exerts great influence in this respect is shown by a glance at the relation between the wings and the body. But that in the case of most of the animals examined the relation between the air and the substance of the body exerts an influence upon the maintenance of the abdominal position is shown by the circumstances that with the exception of a few they were forced upward in water (specifically heavy) in the same position in which they fell to the ground when in the air."

Amans expresses a similar opinion. "We are obliged to regard the manner in which the body of wasps is held as a means for accomplishing longitudinal stabilization. The lower surface of the body is strongly convex and we know that with such a curvature stabilization is automatic. This can be demonstrated experimentally by allowing a sheet of paper bent into a concave convex form to fall to the ground—it will always fall upon the convex side."

Bethe's subjects of experiment and Aman's convex sheet of paper coincide with respect to the fact that they have no individual mobility. They resemble perfectly the passive hovering or floating organisms which assume a definite position with regard to space within the medium which surrounds them, and which automatically revert to that position when their equilibrium is disturbed.

[11]Bethe. Weber die Erhaltung des Gleichgewichtes. Biolog. Centralbl., vol. xiv, 1894.

But the views of Bethe and Amans fail to correspond with the actual facts. My experiments with insects which lack static sensory organs (wasp, sphinx, etc.), have proved that such insects as well as the Diptera promptly react to every disturbance of the position of equilibrium by means of compensatory alterations of the plane of vibration or of the amplitude of the wing-beat, *i. e.* that they perceive disturbances of equilibrium and actively return to the position of equilibrium by means of pressure steering. This is by no means singular since the orientation of animals in space is not invariably accomplished through static sensory organs, but is also assisted by the sense of light. Bethe omitted to take into consideration in his experiments that there are very few insects which are capable of hovering. The overwhelming majority are obliged to make sudden and sometimes rapid wing-beats in order to generate an effective forward impulse and upward impulse.

DISINFECTION BY HOT AIR.

WHEN hot air is used for disinfecting purposes the result is due to two factors. Certain sensitive micro-organisms are killed by desiccation, especially the plant forms which contain about 80 per cent of water. The spores are generally very resistant since their cellular body consists of a highly concentrated albuminoid substance which contains very little water and since they are also protected by membranes of cellulosic character. Hot air also kills by the coagulation of living protoplasm and this effect is produced more rapidly by moist heat (steam) than by dry hot air. Steam also has the advantage of penetrating the articles to be disinfected more rapidly than does dry air; the latter penetrates articles of large size very slowly because the air which they contain forms an obstacle.

Unfortunately, however, steam is very apt to affect clothing and other articles injuriously; it causes the fading or running of colors, alters the surface of leather, causes spots of rust on metal, makes glued articles come to pieces and affects the shape of certain articles of clothing; moreover, it is more costly to use than dry hot air. These various considerations have induced Mr. H. Rautmann to attempt to improve the dry air method by raising the air to a bactericidal temperature and by forcing it to penetrate the objects to be disinfected by means of violent agitation. The apparatus employed is described in *L'Igiene Moderna*. It consists of a closed chamber in which hot air is made to circulate with great rapidity by means of an electric motor. Since the air which circulates is unchanged the quantity of heat required is very small and the expense is correspondingly low. A metal thermometer is attached to an electric contact apparatus in such a manner that when the temperature has reached a certain degree the fuel combustion diminishes automatically, while it is increased, on the other hand, whenever the temperature falls below a certain limit. In this way great uniformity of temperature is obtained in the interior of the disinfecting chamber. Actual tests in different parts of this chamber at the end of half an hour, showed only three degrees of difference (155° C. and 158° C.). The author experimented with the lice found on swine; these were enclosed in woolen bags and placed in the apparatus. They were found to be dead in from fifteen to sixty seconds—in the same way the spores of anthrax and the typhoid bacillus were completely destroyed.

Animal parasites of various kinds are readily destroyed by a few minutes' exposure. Among the bacteria the plant forms were quickly killed as soon as the temperature reached 100° C. (212° F.) and since most pathogenic germs have no spores this temperature (that of boiling water) is sufficient to disinfect articles contaminated with the germs of typhoid fever, cholera, small pox, influenza, dyphtheria, tuberculosis, glanders, chicken cholera, etc. The apparatus can also be employed for destroying spores by raising the temperature of the air to the required degree.

Do Animals Ever Use Artificially Improved Tools?

Some Examples of Resourcefulness and Ingenuity

A WELL-KNOWN German writer on natural history, Wilhelm Boelsche, recently propounded to the readers of *Kosmos* the interesting query as to whether there exist authentic cases of the use of artificial tools, *i. e.* of special implements to serve special ends, on the part of the lower animals. Mr. Boelsche inclines to the belief that instances of such nature do occur, but considers the question still an open one and invites his readers to express their views upon the matter either in the negative or the affirmative, as the case may be. Meanwhile he cites certain instances which may be considered as bearing on the question, quoting freely from such established authorities as Doflein and Bugnion. He calls attention to the fact also that some scientific men hold that the eoliths, or shaped stones of the Tertiary Age, which are generally believed to be the first tools devised by the dawning intelligence of man, may really have been made by some superior member of the Primate Family. In either case the question is fundamental both with respect to natural history and to the first glimmerings of that evolution of the powers of the human brain to which we give the name of "culture."

One of the first examples given by the author is quoted from Prof. Franz Doflein of the University of Breslau and concerns the ant known as the *Oecophylla smaragdina*, of which this authority has made a close study. These insects do not build their nests in the ground, but high in the open air,

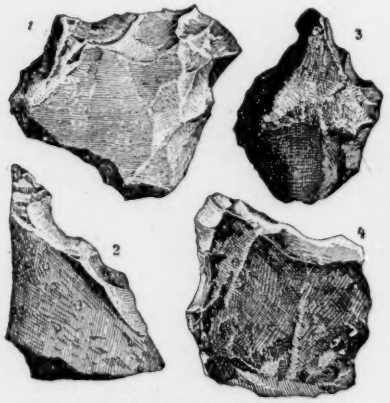


FIG. 1. PRIMITIVE TOOLS OF MAN
1 and 2 show simplest shaped implements made by Tasmanians; 3 and 4 so-called eoliths of the Middle Tertiary Epoch supposedly the first artificially-improved tools made by man (taken from Klaatsch and Verworn).

FIG. 2. LEAF NEST MADE BY OECOPHYLLA SMARAGDINA AFTER DOFLEIN
Reproduced from Sajo, *Ameisenstaat*.

forming them by spinning together the living leaves of bushes and trees (Fig. 2). When Doflein tore apart two of the leaves forming such a nest he observed that a line of ants ranged themselves along the edge of one leaf, holding fast to it with all six feet and stretching out their heads until their mandibles were able to lay hold of the edge of the opposite leaf. "Then," says Doflein, "they slowly and cautiously drew backward, walking carefully backward, one foot behind the other, so that the two leaf-edges which had been split apart gradually approached each other" (Fig. 3). Other observers, remarks Boelsche, not only confirm this, but have even seen ants form a chain quite like a line of gallant firemen, until the foremost was able to seize the edge of the further leaf, in cases where the split was unduly wide. But when the two leaves have been drawn together the domicile is still imperfect. The edges must be attached to each other, and the workers are unable to accomplish this, since they themselves possess no spinning glands. But what does it matter? These barren but resourceful females run to the nursery, tenderly pick up their better equipped infant charges, and rush again to the breach in the walls, and let the babies bind it together once more with the tiny but tenacious threads they spin (Fig. 5). Doflein thus describes this curious operation: "They were by no means merely seizing the larvae in order to carry them to a place of safety, but came straight to the very point of danger, namely the breach in the walls of the nest. Arrived here they clambered about behind the row of ants which held the edges of the leaves together and moved their heads in a curious manner. They held the larvae firmly between their mandibles, seeming to exert a considerable pressure upon the middle of the body. This pressure may be of considerable significance, since possibly it exerts a stimulus upon the spinning glands. The scene presented a remarkable aspect as the workers clambered with their burdens along the line of those who were holding the fort, so to speak. While the latter took their position upon the outside of the nest the former carried on their labors upon the inside and were therefore more difficult to observe. However, after a little while I was able to see quite clearly that the workers held the larvae with the pointed head end of the latter directed upward and to the front and moved them continuously backward and forward from one side of the rent in the nest to the other. While doing this they first paused for a little while on the near side of the breach, as if attaching the thread spun by the larva to the edge of the leaf by pressing the larva's head against the leaf-edge; they then thrust the head across the split to the edge of the opposite leaf and repeated the same process there. As this continued one could see the cleft gradually filled in by a fine silky web spun by the larvae. The fact could not be doubted that the ants were using their young at once as spindles and as weaver's shuttles. Boelsch quotes Karl Escherich, the author of *Die Ameise* (Ants), to the effect that the feat described above is "probably the only case in the animal kingdom in which an animal makes use of a tool." The former writer, however, thinks this example, interesting as it is, does not answer his actual question, which concerns the use of *improved* tools, *i. e.* an implement in some sort modified by the user to serve his purposes, and thus differing, as does the eolith, from some natural object, such as a stick or stone, which men doubtless employed for one purpose or another, such as the beating of skins or the crushing of grain, before they conceived the idea of shaping one stone by means of striking or grinding it with another. The same objection holds good to various other acts of animals which might be cited in this connection, such as the ejection from his funnel-shaped burrow by the ant-lion of grains of sand which may strike some unhappy insect victim and thus facilitate his descent into the Avernus of the trap laid for him. Somewhat similar to this instance is that of the drops of water which are squirted by a certain Siamese fish at insects upon the bank of the stream. Again, apes can often be seen in the zoo cracking nuts with a stone as our earliest forefathers doubtless did, and as small boys do today. It has even been noted that the same monkey, or even a whole tribe, will employ the same stone—of a specially fit kind—time after time, until the stone is worn smooth from use, but of course this cannot be considered the conscious bettering of a useful implement, and never has a monkey been seen, according to Boelsch, to make use of a second stone to improve the shape of the first. However, he mentions in this connection a story told by Heck of a captive chimpanzee in Teneriffe who was accustomed to knock bananas off the bunch with a stick, and which, upon one occasion, when he had been offered a hollow

cane for this purpose, which proved to be too short, stuck a smaller cane inside and thus achieved his object. This certainly looks like a purposeful improvement of a tool.

Finally, Mr Boelsch refers to the acts of certain birds which have some bearing upon this question. Thus the great black Arara cockatoo of New Guinea, cracks certain extremely hard nuts in a very intelligent manner, first weakening the shell by sawing it with his hard beak and then breaking it. Furthermore, to keep his bill from sliding off the smoooth and slippery surface of the nut the bird wraps a bit of leaf about

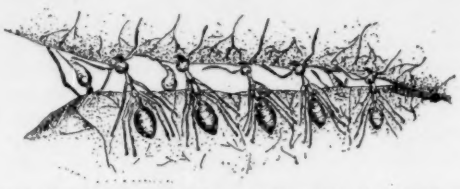


FIG. 3. ANTS (*OECOPHYLLA SMARAGDINA*) MENDING A RENT IN THEIR NEST
After Doflein. From Sajo, *Ameisenstaat.*

to hold it steady while he operates on it. But of course in this case since the beak is one of the animal's own organs it can hardly be called a tool.

Still more remarkable, perhaps, is the practice of the large mottled wood-pecker called "the blacksmith wood-pecker." This bird is accustomed to thrust hard pine nuts into holes or crevices in the trunks or branches of trees, setting them upright so that they are held as by a clamp, thus enabling the bird to extract the seeds with greater ease. As Boelsche observes, this is quite workman-like in principle. But the woodpecker often improves such a natural "vise" (which he makes use of repeatedly, as of a tool ready to hand) by hacking it with his beak, or he may even hammer out a hole to begin with if a natural one is lacking.

In conclusion the author asks his readers, as we have said, to furnish him with similar instances bearing on the direct intelligence of animals in making use of tools or in bettering

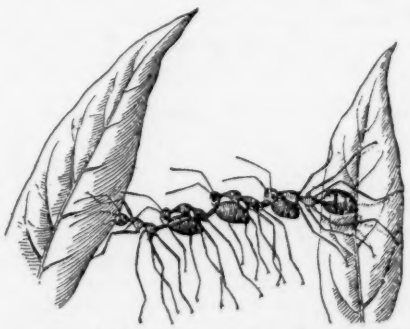


FIG. 4. ANTS (*OECOPHYLLA SMARAGDINA*) FORMING A CHAIN IN ORDER TO MEND THEIR NEST
After Bugnion, from Escherich, *die Ameise* (Ants).

the latter for the attaining of a given end, and the editors of *Kosmos* add a final note expressing the hope that the request will bring forth an instructive discussion of the matter, promising to forward communications to Mr. Boelsche.

THE OIL IN PEANUTS.

DURING the last few years in which there has been an urgent need of fats to be used for food and glycerin for explosives ,the subject of vegetable oils has received more than ordinary attention. Corn, oats, wheat, peach seeds, cherry seeds, prunes, olives, and the various nut kernels have each been carefully investigated as to their oil content, and the character and chemical properties of each oil accurately determined. It is thought that to repeat a similar study with the oil peanuts might not be without interest.

We procured a quantity of the fresh unroasted peanuts and removed the shell and adhering husk. The bare kernels were cut on a watch-glass with the aid of a knife. Twenty grms. of the chopped kernels were transferred in a "fat-free" sack to a Soxhlet apparatus, and extracted, with boiling ether for twenty-five and a-half hours, when it was found that all the oil had been extracted. The ether-oil mixture was transferred to a distillation flask, where the constituents were separated by fractional distillation. The oil as obtained was clear and slightly yellow in color, and made up more than 50 per cent of the weight of the original kernels.

The first experimental work on the peanut oil was to determine the iodine number. This we did by the Hanus method, and found the iodine number to be 94.5 and 95 respectively in two samples.

Another necessary procedure in the analysis of a specimen of oil is to determine its saponification equivalent. By the saponification equivalent we mean the relative amount of saponifiable oils in a given fat, expressed in terms of mgrms. of potassium hydroxide, that were used to saponify the oil.

FIG. 5. (*OECOPHYLLA*) WORKER MAKING USE OF A LARVA TO SPIN WITH
After Doflein. From Sajo, *Ameisenstaat.*

We proceeded with the saponification of the peanut oil, using the Koettstorfer method. The results obtained were 197, 200, and 202 respectively. This value is about 2 per cent. higher than the equivalent found by former workers.

The chemical composition and conduct of peanut oil (more often called arachis oil) is very similar to olive oil, and this fact has led a few dealers to adulterate the pure olive oil with this cheaper oil. The similarity of these two oils makes it difficult to determine accurately the percentage of each in a mixture. In a book, "Edible Oils and Fats," C. Ainsworth Mitchell makes a comparison of the typical values of the arachis and the olive oils as follows:

	Sp. gr.	Saponification No.	Reichert-Meissl.	Hehner value.	Iodine value.
Arachis	0.917	185.5	0.48	95.5	92
	0.9256	196	—	—	100.8
Olive	0.916	185	—	94.0	79.0
	0.919	196	—	96.0	93.0

The most reliable method of differentiating between the pure oils and a mixture of the two is to make a quantitative determination of the mixed arachidic and lignoceric acids. The method to be used involves the separation of the two lead salts by means of ether. These acids are recovered by crystallization from hot alcohol.

The well-known fact that glycerides of the oleic acid series may be converted into isomeric compounds by nitrous acid gives us the basis for the elaidin test, which we use in further investigation of the oil sample. Two cm. of the oil were mixed with an equal volume of concentrated nitric acid and a pale rose color was noticed after one minute. When heated on the water-bath for five minutes the mixture became yellowish brown. After cooling and standing at room temperature for twenty-four hours the mixture was solid.—*Nelda Schule* and *Harold L. Maxwell* in *Chemical News* (London).

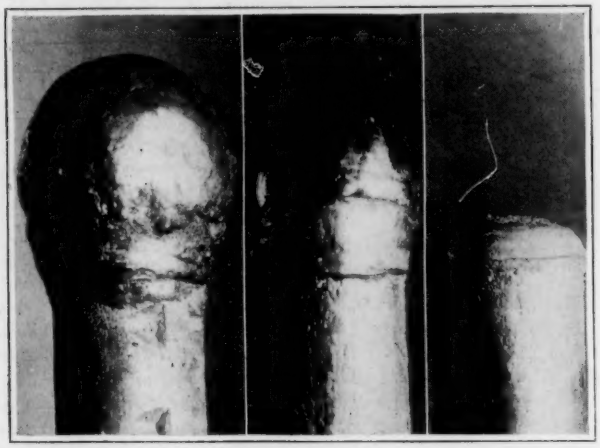
A Theory of Metallic Arc Welding*

Metal Said to Be Projected from Electrode by Suddenly Formed Vapors

By Ralph G. Hudson

IN THE summer of 1918 the welding committee of the Emergency Fleet Corporation initiated an investigation of metallic arc welding in which special attention was to be given to the determination of the cause and nature of the transmission metal from an electrode to a plate. Although metallic arc welding had been employed successfully for a considerable period, it was appreciated that its application was based upon empirical methods, and to make greater use of such welding in shipbuilding it was evident that its basic principle should be investigated as thoroughly as possible so that inferior methods of metallic arc welding might be eliminated. The object of this paper is to present the results of an investigation of this character conducted in the laboratories of the Massachusetts Institute of Technology.

It should be noted that at the beginning of this investigation no satisfactory explanation had been given for the transmission of metal from electrode to plate. In downward welding the deposition of metal might be attributed to gravitational



Courtesy of the Electrical World and the American Welding Society

FIG. 1. EFFECT OF ARC LENGTH UPON SIZE OF ELECTRODE GLOBULE

At the right, a globule developed with a very short arc; in the middle, with a moderate length of arc; at the left with a very long arc. These are 3/16 in. electrodes magnified 6.8 diameters. The current strength in each case was 100 amp. Each globule contains a cavity; in the smaller globules, the cavities are usually open and resemble small drill holes, while in the larger ones they are usually closed and are surrounded by a thin skin of metal.

force, but in upward welding no such explanation could be offered. The fact that an electric current is employed in the process suggested the possible existence of forces of electrical origin which might pull metal from the electrode to the plate. Calculations of the magnitude of the electrical forces that may exist during metallic arc welding indicate that they are negligible and may therefore be eliminated as possible causes of the action. This view is further substantiated by the fact that satisfactory welding may be performed with current flowing in either direction or with alternating current, and that such differences as may exist with different directions of the current may be explained by consideration of the relative heating properties of such currents at the terminals of an electric arc.

In conducting this investigation the writer, following the suggestion of the committee, first attempted to obtain a photograhpic record of successive phases of the welding arc by means of a high-speed motion picture camera. Owing to the intense luminosity of the arc itself, however, the films thus exposed show only various shapes of the arc itself and an occasional view in silhouette of the electrode, molten drops and plate. The principal use made of these films was to examine them one by one with a low-power microscope with transmitted light, the observations being noted later.

Instantaneous photographs of the welding arc obtained with a short-exposure focal-plane shutter suffered from the same domination of the plate by the arc to the exclusion of all other phenomena. While focusing the camera, however, it was realized that more could be seen with the eye on the ground glass than could be obtained photographically or by direct observation through dense glasses, so the writer began an extended study of metallic arc phenomena as seen in magnified form on the ground glass. In this manner the action of the arc could be examined without screening the eyes and with the further advantages offered by magnification and observation of the action in its true color.

When an arc is struck between a steel electrode and a steel plate the end of the electrode and a spot on the plate are heated to a high temperature and metal is transferred from the electrode to the plate. The electrode is heated to a higher temperature than the plate because the heating action of the arc is more concentrated in the case of the electrode and because the heat conduction away from the hot spot is greater in the case of the plate.

Since the melting points and other thermal constants of the elements[1] and their compounds in steel electrodes vary widely and their chemical affinities are quite different, it is to be expected that the constituents of an electrode subjected to a high temperature will change from solid to liquid or gaseous form successively and not at the same instant. Since the melting point of iron is higher than that of any other constituent of an electrode with the exception of carbon, which combines rapidly with oxygen at welding temperatures to form carbon monoxide, it is furthermore to be expected that in the welding process the iron constituent of the electrode will melt last.

The thermal changes just described are known to take place during the application of heat to any complex substance. In metallic arc welding the temperature changes which take place differ to a marked degree from the changes incident to the usual methods of heating metals in that a small mass of the electrode in welding is subjected to a high temperature for a very short interval of time. The distinctive thermal feature of metallic arc welding is then the sudden rise and fall of temperature in the metal transmitted to the plate. Under the circumstances it may be seen that the melting of the iron is delayed by the heat absorbed by the other constituents of the electrode and that this fact, together with the limited time of application of high temperature, disproves the possibility that the iron is completely vaporized in the welding process. For example, when a projectile is fired from a large gun, the initial temperature of the gas behind the projectile is believed to range between 3000 deg. and 4000 deg. C. Although this temperature greatly exceeds the melting point of the material of the projectile, there is little evidence of melting on the surface of the projectile because the projectile is not heated by the adjacent gas for a period long enough to melt its surface.

An increase of temperature in most materials is usually accompanied by an immense change in volume. While various changes in volume may take place among the constituents of

*Abstracted by the *Electrical World* from paper presented before American Welding Society.

[1]An analysis of steel electrodes usually reveals the presence of at least ten elements: iron, carbon, manganese, copper, sulphur, phosphorus, silicon, oxygen, nitrogen and hydrogen.

the electrode during metallic arc welding, the greatest possibility for such expansion may be found in the formation of carbon monoxide. It is therefore to be expected that a globule will be formed by such expansion on the end of the electrode during welding. Typical electrode globules developed in this manner by various lengths of arc during the welding process are shown in Fig. 1. Each globule contains a cavity which may be seen clearly during welding on the ground glass of the camera described above and is also present in the cold con-

Courtesy of the Electrical World and the American Welding Society

FIG. 2. SURFACE OF AN ELECTRODE ON THE ELECTRODE SIDE OF A LARGE GLOBULE

tracted globules shown in the figure. In the smaller globules the cavities are usually open and resemble small drill holes, while in the larger globules the cavities are usually closed and are surrounded by a thin skin of metal.

An electrode globule maintained in continuous contact with the plate to prevent the formation of the glaring arc and heated by a heavy current may be seen under magnification on the ground glass to expand and blow out minute particles at high velocity from the thinnest side walls, a contraction of the globule occurring after each expulsion of particles. The particles appear to originate in the inner electrode surface of the globule. If the globule is suddenly detached and the arc interrupted at the same instant in ordinary long-arc welding, the inner electrode surface of the globule presents the appearance shown in Fig. 2. The pitted electrode surface suggests irregular fusion due to different temperatures of fusion, vaporization and chemical combination of the ingredients under the influence of rapid changes in temperature.

Owing to the complex structure of the electrode, it is not easy to determine the exact nature of the vapor content of the globule. That the vapor consists partly at least of carbon monoxide gas is suggested by the fact that such globules do not form in general when the end of the electrode is heated in a reducing (deoxidizing) atmosphere. It is found impossible to weld with an electrode containing practically no carbon in a reducing atmosphere. In welding under water it was observed that bubbles of gas rise continually to the surface of the water and burn, indicating the possible dissociation of the water with the absorption of oxygen by the electrode and the rejection of hydrogen to the surface of the water. After a globule had been maintained for several minutes at high temperature in contact with a plate in air, it was observed that all expulsion of particles ceased. It may be inferred from this that all of the vapor-forming constituents of the globule had been burnt out.

If the electrode while welding is suddenly swept across an adjacent insulated flat surface, small spots of metal are found on the surface at regular intervals over the surface traversed by the hot electrode. (A magnified view of one of the spots is shown in Fig. 4) The same effect was observed by holding an incandescent electrode—just removed from ordinary welding—over the rim of a revolving wheel. It was determined in this way that the average frequency of projection was approximately one-fifth of a second, the projection terminating with the cooling of the electrode.

It would appear from the observed facts that the metal deposited during metallic arc welding is transmitted, in part at least, in the form of minute particles which are projected from the electrode globule by the internal expansion of some vapor, possibly carbon monoxide. The expelled particles pass through the arc too rapidly to become vaporized and reach the plate in a fluid state. If the expelled particles strike solid metal, they either ricochet along the surface—which ex-

Courtesy of the Electrical World and the American Welding Society

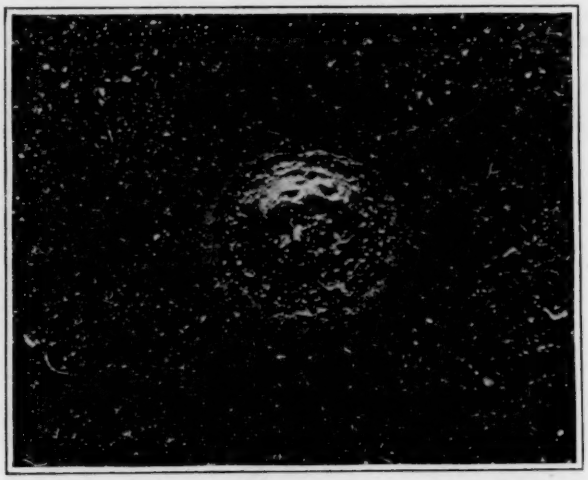
FIG. 3. DUST MAGNIFIED 20.7 DIAMETERS WHICH ACCUMULATES AROUND THE WORK DURING METALLIC ARC WELDING

plains the accumulation of iron dust in the welding room—or flatten out without fusion, the most common cause of poor welds. If the particles strike a fluid metal, they penetrate the fluid and solidify with the molten surface of the plate.

It is a well-established fact that the best welding is obtained with the shortest arc and the worst welding with the longest arc. It will be noted in Fig. 1 that the size of the electrode globule also increases with the length of arc, the best welding being obtained with the smallest globule. A small globule implies greater concentration of projected particles in the direction of the opposite fluid spot. In downward welding a large globule becomes elongated by gravity, the lower part of the hollow globule becomes thickened by downward flowing metal, the side walls become stretched and thinned, and particles are projected wastefully through the side walls at right angles to the arc. The globule as a whole frequently breaks away from the electrode and drops without

fusion on the plate. Electrode ends rejected by a welder and presenting the appearance shown in Fig. 1 constitute substantial evidence of ineffective long-arc welding. In upward welding a large globule tends to fall to one side or the other by gravity and prevents the efficient projection of metal.

Any material which serves to increase the melting point of the surface of an electrode must, in accordance with the stated theory, improve the conditions under which particles are projected from the electrode globule. The cup-shaped surface formed at the end of such an electrode will reduce the amount of indirect projection of particles to a minimum, and the increased stability of the arc will reduce the difficulty of manipulation of the electrode, since the length of arc may be varied over a greater range without interruption. It would appear that most of the coatings suggested for electrodes perform the function of cooling the surface of the electrode by vaporization and in some instances, owing to the rapidity



Courtesy of the Electrical World and the American Welding Society

FIG. 4. A HIGH MAGNIFICATION (16.7 DIAMETERS), OF A NUCLEUS OF METAL PROJECTED ON A COLD PLATE FROM AN INCANDESCENT ELECTRODE GLOBULE

of the action, remain in a fluid condition about the sides of the electrode globule. It should also be noted that since oxide (rust) has a higher melting point than steel, rust should not be removed from electrodes and that rusty electrodes will usually work better than bright clean ones. In many cases the outside layer of bare electrodes may be changed by drawing and heat treatment so that it has a higher melting point than the interior. The ideal electrode would have a high melting-point shell—tungsten for example—surrounding a lower-melting-point interior containing sufficient vapor-forming constitutents to eject metal constantly when heated.

The writer would suggest certain promising subjects for further study: First, a determination of the character of the vapor found in an electrode globule; second, a determination of the best surface material for electrodes, first cost and effect on the finished weld to be considered; third, the effect of welding in a reducing flame upon the character of the weld—the writer has found that such a weld is more ductile and reveals less formation of nitride; fourth, an investigation of the value of welding under water as in the case of ships, tanks, etc.; fifth, the use of materials other than steel in metallic arc welding.

PROTECTIVE RESISTANCES FOR HIGH-TENSION INSTALLATIONS.

CARBORUNDUM and similar materials behave as though they were a mixture of conducting and non-conducting bodies and their resistance decreases with increase of voltage. This allows their use as protective resistances in parallel on current transformers, trip coils, etc. With the occurrence of a pressure surge their effective resistance is reduced to a small per cent of its original value. The surge passes then through the short-circuit which is thus provided for it, after which the normal value of the protective resistance is restored so that the apparatus it protects can again function properly.

However, this characteristic of silicon-carbide resistances becomes undesirable when they are connected in series with pressure transformers, etc., when it is desirable to maintain the resistance at high voltage. By long rods or disk elements used for resistances to be connected in parallel it is possible to reduce the amount of this variation of resistance with applied voltage, but it is not possible to eliminate it altogether.

From a study of the silicon carbide resistances it was concluded that their decrease at high voltages is not due to temperature effect but rather to the nature of their composition. It was thought then that in order to eliminate this variation in resistance a metallic connection must be provided between the terminals. This condition and the necessity to secure high resistance makes it desirable to employ a coherent conducting mass as a core with which other materials, of higher or lower conductivity, can be combined. The oxides of certain metals possess such desirable properties. Copper oxide (CuO), for example has a conductivity of 400 ohms per ccm. and melts at a reasonably low temperature. The CuO is cast in form of rods which have high mechanical strength and which are coppered at the ends in order to obtain good electrical connection. Melting the CuO causes a considerable part of it to be reduced to C_2O which has a specific resistance of only 40 ohms per cm-cube. By adding other materials it is possible to vary the effective resistance over a wide range. Whether the resulting material is a compound or a solid solution has not been ascertained.

A series of tests showed that the resistance of carborundum elements offered to high-pressure surges was only one or two per cent of that obtained by a 2-volt d.c. bridge, whereas the high-voltage resistance of the new copper-oxide elements varied from 50 to 70 per cent of the values measured by the bridge. There are two reasons for the resistance drop in the latter case: 1. Sparking over the surface of the short-resistance bars provides a parallel circuit between terminals. 2. The resistances have a certain capacity which produces an appreciable displacement current at high frequencies. The resistance drop varies with the frequency and is therefore greater, the shorter the length of overhead line.

Experimental data given show that better protection is obtained by using the oxide resistances. A specific resistance of about 5,000 ohms per ccm. is obtained in oxide rods about 20 mm. diam. and 60 to 100 mm. long; higher resistances could be obtained by adding other materials. Another advantage of the new resistances is their high negative temperature-coefficient, which makes it possible for them to carry heavy loads without injury. For instance, a 12,000-ohm unit will carry 4.5 amperes without reaching a dull red heat; this means that the resistance must be diminished very considerably, otherwise the power dissipated in the resistance would exceed 250 kw., which would melt it at once. The high heat capacity of the resistances results in their being unaffected by heavy surges of current at times of short-circuit.—*H. Gewecke* in *Elektrotechnische Zeitschrift*, July 31, 1919.

USE OF ELECTRICITY IN THE ORANGE GROWING INDUSTRY.

ELECTRIC pumping is but one feature of the use of electrical energy in the orange industry. The orange packing-house is today operated entirely by electricity. The fruit is washed by electrically driven washers. Then the brand label is placed on it by another electrical device. The orange then finds its way into the electric sorter, in which the oranges are graded for the market. Even the boxes are made and nailed up by electrical machinery, and in some of the largest packing houses there are many labor and time-saving devices, which get their power from electric motors.—Abstracted from *Electrical Review*.

The Ultra-Rapid Cinematograph

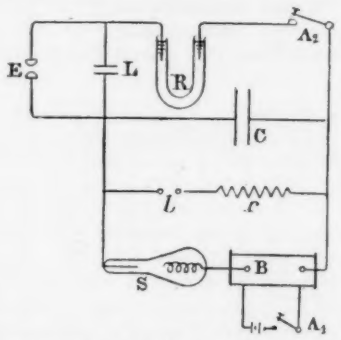
Taking Pictures at the Rate of 20,000 Per Second

AT a recent session of the French Academy of Sciences, Dec. 1, 1919, a report was made by Messrs H. Abraham, E. Bloch, and L. Bloch, stating that they had been able to register moving picture images of the remarkably high frequency of more than 20,000 per second. While the applications of such a system of cinematography are limited to very special cases, they nevertheless possess very great scientific uses as will appear in the following statement by the authors:

In the study of certain very rapid movements and in particular in certain problems of ballistics, the analysis of the phenomena cannot be undertaken except by the cinematographic method. But the latter requires in such cases an extreme degree of rapidity, as much for example as 20,000 or even 50,000 photographs per second. . . .

Much important research has already been conducted along this line. We shall here confine ourselves to citing that by M. Bull with which our own researches are connected. At the Institute Marey M. Bull succeeded in making cinematographs at the rate of 3,000 photographs per second. He operated with the objective uncovered and with a continuous movable film, illuminating the object by a series of sparks proceeding from the condensed discharge of a Ruhmkorff coil; this is the same device already employed by Boys for taking instantaneous photographs of projectiles.

The device employed by us during the past year enables us to raise the frequency to a very high degree. The principle consists in charging up to about 5,000 volts a small Leyden



ELECTRICAL CONNECTION OF THE ULTRA-RAPID CINEMATOGRAPH

jar, which is immediately discharged in a discharger, being then freshly charged from a source of high tension electricity (12,000 to 15,000 volts). The regularity of the discharge is secured by a vigorous blowing of the sparks, the effect of which is to prevent the disruptive spark from passing to the arc.

In default of a continuous current or of a battery of accumulators, one may employ as a high tension source a strong condenser which has been previously charged and forms a reservoir of energy. Or one can also make use of the secondary circuit of a transformer in which the primary tension has been abruptly established.

In the diagram condenser C, insulated for 20,000 volts, has a capacity of the magnitude of a demi-micro-farad. It is given a charge of from 12,000 to 15,000 volts, by means of a transformer or else by a Ruhmkorff coil B, provided with a thermo-ionic valve or with a Villard valve, S. The condenser C is protected by a tension-limiting discharger *l*, provided with a series resistance in *r*. An electrometer (not represented in the diagram) is likewise shunted in thus permitting us to follow the voltage of the charge.

The capacity of C is sufficient to supply the Leyden jar L a great number of times without its own potential being perceptibly lowered. In order to avoid any disturbance proceeding from the coil B during the taking of the photographs, it is advisable to cut the primary of the said coil with an interrupter A_1, which opens automatically at the moment of the photographic operation. At the same instant the interrupter A_2, placed in the circuit of discharge, is suddenly closed. Furthermore, since the supply of energy from C is limited, it is well to provide a third interrupter (not shown in the diagram) which cuts the circuit of discharge at a convenient moment, for example, after the taking of from 100 to 200 photographs. The small Leyden jar L, having a capacity of less than one thousandth of a micro-farad, is charged through an adjustable liquid resistance R. It is the latter which determines the value of the average current yielded by the intermittent discharges, thus determining the frequency of the sparks.

The circuit of discharge EL is very short in order that the sparks may be extremely brief in duration. These sparks which are extremely photogenic, serve to illuminate the movable object, and since the durations of the illuminations are of the magnitude of one millionth of a second, the photographs are practically instantaneous. The discharger E is formed between aluminum hemispheres which are thoroughly cleansed with fine emery cloth before each operation; the distance of discharge is about one mm.

We are thus able to obtain, without difficulty, a spark of frequency exceeding 50,000 per second. The photographs must be taken upon a sensitive film having a very rapid movement. Our first tests were made with disks covered with gelatinous-bromide paper 20 cm. in diameter, driven by the shaft of a ventilator motor having 6,000 revolutions per minute. Better results, however, appear to be obtained by rolling a sensitive film around a cylindrical drum in rapid rotation according to the method of M. Bull, who has thus obtained remarkable moving pictures of the motion of projectiles.

We may sum up the matter by the statement, that thanks to the employment of continuous discharges broken up by blowing, it is now easy to take moving pictures at a rate of speed exceeding 20,000 photographs per second.

MOTION PICTURES IN SWITZERLAND.

MOTION pictures have not, as yet, penetrated to all sections of Switzerland, but reports show that progress is being made from day to day. The war had a very stimulating effect upon the industry, all the belligerent countries having used this means for propaganda work; and while no one can state what effect this propaganda had upon individual opinion regarding the war, it has had the result of converting the people to this form of amusement. Compared with other countries and considering the population, Switzerland possesses today a relatively small number of motion-picture theaters and none at all of any great seating capacity. As a result, the smaller houses are very well patronized.

The production of motion pictures has not been undertaken to any extent in Switzerland, there being at the present time but one concern and it is not important. However, several of the large French and German producers have, at various times, utilized Swiss mountain scenery for staging scenarios. Of the films imported into Switzerland about 60 per cent are of American manufacture, the remainder coming from Germany, France and Italy. Films coming from France are, in many instances, reproductions of American films made at the French agencies of the American producers.—Abstracted from *Commerce Reports*.

The Breakdown Voltage of a Spark Gap*

Effect of Temperature and Pressure

By L. B. Loeb and F. B. Silsbee

THE investipation here described was conducted at the Bureau of Standards for the National Advisory Committee for Aeronautics, in order to determine the necessary minimum potential for causing sparks to pass in a gasoline engine whose compression ratio was known and in which the temperature of the gases before ignition could be estimated.

According to the simple theory (J. J. Thomson, Conduction of Electricity Through Gases; Townsend, Electricity in Gases; and Peek, Transactions of the American Institute of Electrical Engineers, 1910-1916) the sparking potential depends solely on the density of the gas between the electrodes for a given fixed pair of electrodes, *i.e.*, on the total number of molecules between the electrodes. This has been invstigated over a considerable range of pressures, spark distances, and forms of electrodes by numerous observers, but only three investigators have studied the effect of temperature, and then only over a limited range. They all found that the sparking potential depended solely on the density of the gas over the range studied.

In the study of airplane spark plugs it seemed advisable to determine whether this law held for pressures and temperatures which might occur in the cylinders of a high compression engine just before the ignition of the charge. In airplane engines the maximum compression pressures under normal conditions range from 90 to 130 pounds per square inch with temperatures up to 300° C.

APPARATUS.

The experiments were conducted as follows: An ordinary ⅞-inch Titan A. C. porcelain plug was screwed into a steel bomb about 25 cm. (10 inches) long having the design indicated in Fig. 1. There was a thick glass window opposite the sparking terminals when the plug was screwed in position. A high-pressure air tank connected to the bomb through suitable valves served to regulate the air pressure to any desired value. Temperatures were measured by a Pt, Pt-Rh thermocouple, B. S. W5, which was inserted in a steel tube sealed at one end with walls ½ mm. (0.020 inch) thick. This was screwed into the bomb so that its inner end was within 1 cm. of the sparking terminals of the plug. The bomb was placed in a cylindrical electric resistance furnace and packed with asbestos wool, so that only the porcelain insulator was exposed at one end, while the window projected out about 5 cm. (2 inches) beyond the other end.

Sixty-cycle voltage was supplied through a step-up transformer having a ratio of 200:1 and applied between the central electrode and the bomb. A resistance of 220,000 ohms was put in series with the plug to avoid an excessive current and consequent burning up of the terminals when the spark passed. The voltage was read on a voltmeter connected to the low-tension side of an auxiliary step-down transformer. The passage of the spark was made evident both by the kick of the voltmeter and by the appearance of the spark in the bomb. Ionization was provided for by the use of a half milligram sample of radium in most of the experiments, while in some a 50-mgm. sample, placed just below the electric furnace, was also used. This ionization served to eliminate the complicating effect of spark "lag" and made the readings much more consistent and reliable. No striking difference in the readings could be noticed with the two different samples.

The tests were run on three Titan plugs: No. 1 had the regular terminals of Ni-Ma wire 1.3 mm. (0.051 inch) in diameter set at right angles and separated by 1.8 mm. (0.071 inch); No. 2 was a Titan plug with similar terminals 3.13 mm. (0.123 inch) in diameter rounded at the ends, separated by 1.2 mm. (0.047 inch); No. 3 was a plug like No. 1 but with a distance of 2.2 mm (0.086 inch) between the wires. In each case the spark passed between the cylindrical surfaces of the wires near the point of closest proximity.

PROCEDURE

The readings were taken as follows: The temperature was run up to the desired value and held constant from 15 minutes to half an hour. There were fluctuations at the higher temperatures of as much as 10 degrees either way so that a mean temperature was chosen as representing the true conditions. The breakdown voltage of the gap was then determined by at least 10 trials for each pressure. The pressure was increased in steps of 10 pounds per square inch. The pressures were read by two small pressure gages whose ranges were from 0 to 100 pounds per square inch. The spark potentials were read to as high a pressure as it was possible to obtain without the sparks passing over the outside of the insulator. Then the pressure was reduced in steps of 20 pounds and readings again made. As a whole the return readings checked the first readings well. This can be seen from the plots where maximum sparking voltage is plotted against the pressure for each temperature. As the voltage which could be used without sparking over the outside of the porcelain was about 19,000 volts, no voltages were measured above this. The pressure range over which the measurements could be carried out started from 60 pounds at room temperature and increased until at 200° C., or thereabouts, pressures of 100 pounds could be used.

SPARK PLUG BOMB.

FIG. 1. STEEL BOMB IN WHICH SPARK PLUGS WERE TESTED

From then on the pressures were limited with increasing temperatures by a new phenomenon which may have been caused by electron emission from the hot terminals at high voltage. Under these conditions the spark was replaced by a sort of purple brush discharge (corona) which came on gradually as the voltage was increased.

It was at first thought that this glow discharge might be an important factor in causing ignition trouble. Further measurements were therefore made in the same apparatus but with a Bosch D-C magneto as a source of voltage. With this arrangement no brush discharge could be detected although the observations were carried to 760° C. Above 600° C. the electrical conductivity of the porcelain insulator was great enough to prevent the magneto from sparking at the higher pressures, but there was no sign of brush discharge under any conditions. It is probable that a certain time is required for such a discharge to form and that the very sudden application of voltage produced by the magneto does not admit of this.

RESULTS.

The curves plotted between maximum sparking potentials in kilovolts and pressure in atmospheres may be seen in plots 2, 3, and 4. The results represented by all these curves, except the one for low temperature measurement with the larger terminals could be repeated consistently. It is possible that a

*Abstracted from Report 54 of the National Advisory Committee for Aeronautics.

stronger source of ionization should have been provided, and the voltage increased still more slowly in this case. The slight curvatures of the lines may be due in part to the gages, since no calibration corrections were applied. The direction of the curvature is the same as that noted by other observers.

The data given in the curves were analyzed by first reading from each of the curves the pressure corresponding to a given voltage, say 10,000 volts. From this pressure and the temperature pertaining to the curve, the relative density of the gas is then computed by the formula.

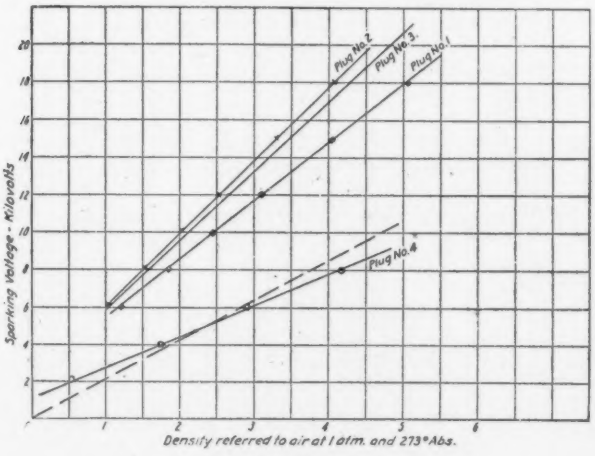
$$\rho = \frac{\delta}{\delta_0} = 273 \frac{P}{T}$$

where δ_0 is the density at 1 atmosphere and 273° absolute, P is the pressure in atmospheres, and T the absolute temperature

Temperature Abs.	Density at	
	10,000 volts.	8,000 volts.
300°	2.51	1.83
383°	2.46	1.80
455°	2.27	1.80
553°	2.38	1.78
700°	2.59	1.96
Mean	2.45	1.83

in degrees centigrade. This was done for six different voltages on each plug. The table above gives the results of plug No. 1 at 10,000 and 8,000 volts, and is typical of the other data. It is evident that the densities thus obtained are constant within a few per cent over the entire range and show no systematic change with temperature or pressures.

It may therefore be concluded that the breakdown voltage is a function of the gas density only. To determine the form of this function the average values of density obtained as described above are plotted against the corresponding voltage in Plot 1. The curves thus obtained show that the breakdown voltage is a linear function of the density but is not proportional to it. The data can be represented by the following equations:



PLOT 1

Plug No. 1	$E = 2.2 + 3.1\,\rho$
Plug No. 2	$E = 1.8 + 4.0\,\rho$
Plug No. 3	$E = 2.4 + 3.4\,\rho$

Where E is the sparking voltage in kilovolts and ρ is the density relative to air at atmospheric pressure and 0° C. The constants in these equations are of course dependent upon the shape and spacing of the electrodes, and would be smaller for the case of the shorter 0.5 mm. (0.020 inch) gaps used in spark plugs.

In addition to the measurements with alternating current described above, a second series of tests was made, using a Bosch D-6 magneto as the source of e. m. f. and a special crest voltmeter equipment[1] to measure the breakdown voltage.

This equipment consisted of an Albrecht electrostatic voltmeter connected in series with a G. E. kenotron (electric valve) as shown in Fig. 2. This valve permits current to flow when the heated filament F is negative with respect to the relatively cold anode A, but allows no current to flow in the reverse direction. Consequently, a negative charge accumulates on the insulated conductor, formed by the anode and the case of the electrometer, of such amount that when the sparking electrode and voltmeter needle are at their greatest positive potential the filament and anode are at the same potential, and there is no tendency for further charging. During the rest of the time the needle of the voltmeter is near ground potential, but the rectifying effect of the kenotron prevents the charge from leaking off. Consequently the meter comes to a steady deflection which measures the maximum positive voltage applied.

Runs were made with this apparatus at temperatures of 460° C. and 520° C. up to pressures of 150 pounds per square inch, using a Champion (Toledo) plug No. 4 with ×-bend electrodes set with the usual spacing of 0.5 mm. (0.20 inch). The results

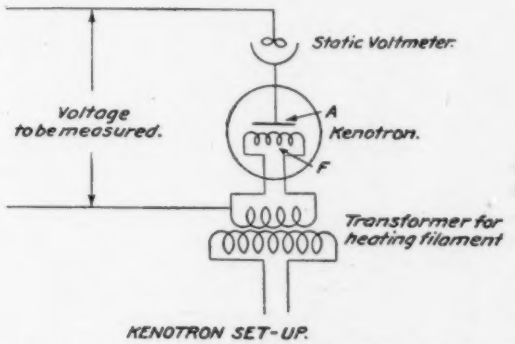


FIG. 2. APPARATUS USED TO MEASURE THE BREAKDOWN VOLTAGE

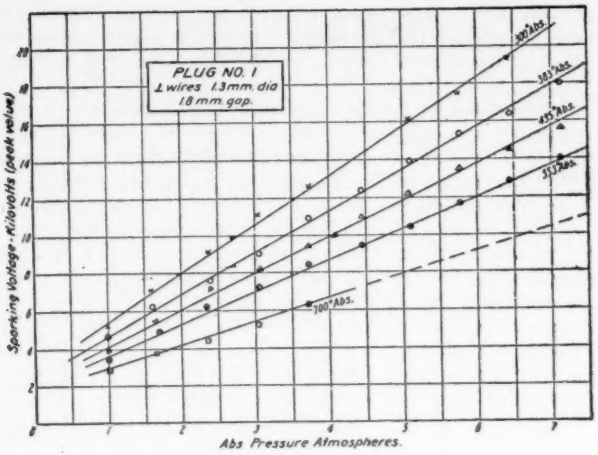
as obtained are plotted in Plot 5 and the combined data from these curves are plotted against relative density in Plot 1, giving a line whose equation is

$$E = 1.1 + 1.7\,\rho.$$

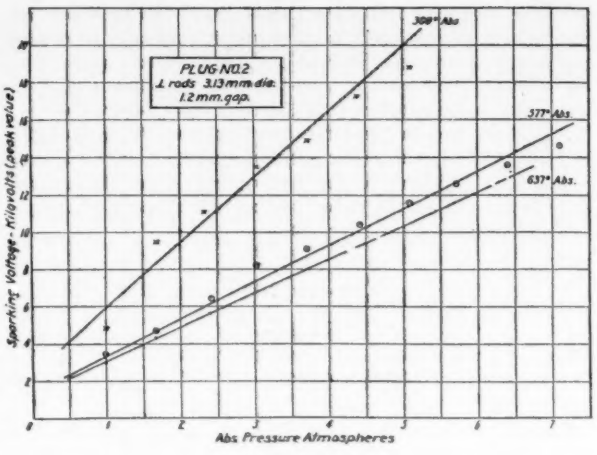
These measurements with the magneto and crest voltmeter showed the presence of a further complication due to the fact that the heat of the spark raised the temperature of the electrodes very materially. This in turn heated the gas near them so that the discharge occurred through gas which was decidedly less dense than the surrounding atmosphere. This was indicated by the fact that at first starting the magneto the voltmeter showed a relatively high voltage (in one case 4,100 volts), which decreased gradually for nearly a minute, after which it remained constant at a much lower value (2,350 volts). The time required for the change implies very strongly that it is a purely thermal effect rather than any ionization due to the preceding sparks, since the latter effect would be almost instantaneous. In the case of a spark plug in an engine cylinder, the central electrode, being insulated thermally as well as electrically by the core, is much hotter than the incoming charge and consequently this effect may be present to some extent.

As a check upon the laboratory data measurements were

[1] *Sharp, C. H., Electrical World*, 69, p. 556, 1917.



PLOT 2



PLOT 3

also made in a Hall-Scott A-5 aviation engine having a compression ratio of 4.2:1. Owing to the late closing of the intake valve and the advance of the spark, the actual ratio of cylinder volume at intake to that at ignition was only 3.2:1. If it can be assumed that the charge in the cylinder is at atmospheric pressure and the temperature at the closing of the intake valve, then the relative density at ignition will be 3.2. Plug No. 4 was run in this engine firing from Dixie "88" magneto. The crest voltage as measured by the kenotron was found to be 5,950 volts. Measurements with a calibrated spark gap having 1 cm. spheres indicated 4,500 volts. The voltage predicted for this density from Fig. 2 is 6,400 volts.

In comparing these results it must be borne in mind that the crest voltmeter loses its charge very slowly, so that it really indicates the highest peak occurring during two or three minutes preceding the reading. The parallel spark gap, on the other hand, is adjusted to fire about half the time and probably gives more nearly the average crest voltage. It appears, therefore, that the results obtained in the laboratory are in substantial agreement with those found on the engine, and that the linear relation between voltage and density may be safely applied to ignition circuits.

It will be noted that the results shown in Plot 2 can be represented roughly by a straight line through the origin, such as is shown dotted, and which indicates a direct proportionality between the sparking voltage and density. This relation will be found useful in cases where the voltage is known at some one density and it is desired to estimate it for another density not too widely different. It is unsafe, however, to use this law of direct proportionality to extrapolate over a long range from the sparking voltage at normal atmospheric density to that at very high density.

CONCLUSIONS.

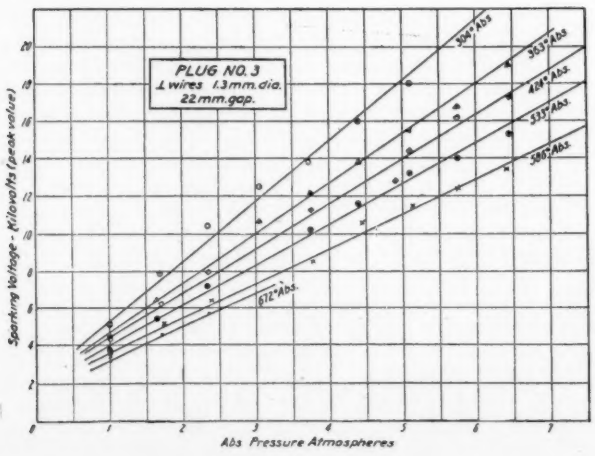
These experiments confirm the relation that the breakdown voltage of a spark gap depends only upon the density of the gas and varies with pressure and temperature only as they effect the density. This relation is found to be valid up to 800° C. and 8 atmospheres pressure. Both the pressure and temperature of the charge in a gasoline engine increase very greatly during the compression stroke, but the sparking voltage can be computed from the linear relations shown in Plot 2 without a knowledge of these variables separately, since the density is determined solely by the original density and the compression ratio. For small changes in density, the assumption that the voltage is proportional to the density may be made.

With the sudden discharge from an ignition coil or magneto a disruptive spark is produced even at temperatures where a 60-cycle voltage would produce a brush discharge.

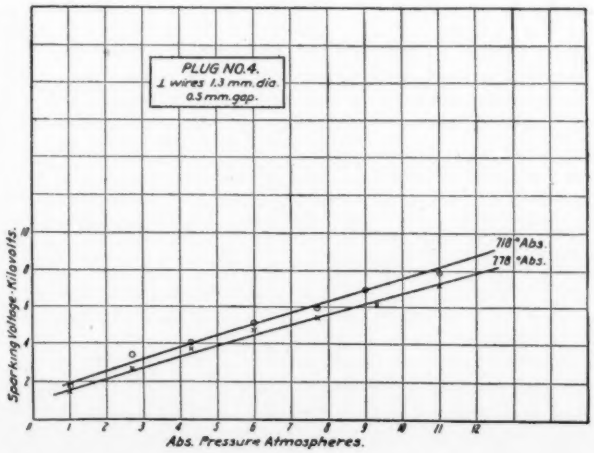
The voltage required for a spark plug set at 0.5 mm. (0.020 inch) in an aviation engine of moderate compression is of the order of magnitude of 6,000 volts.

LARGEST ELECTRIC HATCHERY

THERE is an electric hatchery at Artesia, Cal., which is claimed to be the largest in the world. It has a capacity of 100,000 eggs and produces 30,000 chicks per week.



PLOT 4



PLOT 5

Fatigue Phenomena in Metals*

Summary of Available Facts and Theories Relating to Fatigue Failure and a Discussion of Some Unsolved Problems

METAL parts of machines, such as springs, shafts, crankpins and axles, occasionally fail suddenly while only subjected to conditions of ordinary service. Not only does failure occur suddenly, but the part about to fail shows no ordinary evidence of weakness. The broken parts when examined are seen to be broken off short, and without general distortion, even though the material may show high ductility in ordinary tests. Such failures are found only in parts subjected to stress repeated many times—to "vibration," as it is sometimes stated—and the phenomena which are involved in the final failure of metal through oft-repeated loading are known as "fatigue" phenomena of metals.

The phenomena of fatigue failure have recently given rise to some perplexing problems in connection with the design and service of air-plane-engine crankshafts, the hulls of steel ships, axles and shafts in railway cars, motor cars and trucks and other machine parts. The question whether structural parts subjected to repeated stress are in danger of fatigue failure has been discussed at considerable length. The danger of fatigue failure seems to be an unimportant factor in determining the safety of structural parts, with the possible exception of parts subjected to reversal of stress. The reason for this is probably found in the relatively small number of loadings which most structures are called upon to withstand, and in fact that most of the loadings are below the maximum working value. On the other hand, the danger of fatigue failure is a major factor in determining the safety of many machine parts.

The problem of fatigue of metals engaged the attention of engineers seventy years ago, in connection with car axles and members of iron railway bridges. It was early recognized that high stress tends to cause, or at least to hasten, fatigue failure, and about 180 Wöhler's famius investigations were undertaken to determine the relation between intensity of fiber stress and the ability of materials to resist fatigue under repeated stress. Wöhler's tests occupied some eleven years, and remain to this day the most thorough tests on record. Wöhler investigated metals under direct tension, under bending, and under tension (shear). For some of his tests the stress varied from zero to a maximum, and for others the stress was reversed.

Following Wöhler the famous Bauschinger published a series of conclusions on fatigue, and various other investigators, notably Gerber, and Weyrauch and Launhardt, gave early interpretations of the experimental results of Wöhler and Bauschinger.

In these earlier experiments several facts seem noteworthy. The prime object of the investigators was to deduce laws of fatigue for railway bridges and car axles. The problem of fatigue in high-speed machine parts had not then appeared. These investigators carried their tests far enough to cover the number of repetitions required by the structures of their day and assumed that having done so they had established an endurance limit. Reading their conculsions carefully, the statement does not seem to be made that material which passed their tests would stand an *infinite* number of repetitions. The term generally used is "indefinite" or "very large," and the number corresponding is from ten to fifty millions. For the problem which they investigated their tests seem to give safe guides for practice, but today, with the advent of modern high-speed machinery, some parts of which must be as light as possible, and the extension of the fatigue problem to such members as the cranks and the connecting rods of gas engines and the shafts of steam turbines, the number of repetitions of stress which a machine member may be called upon to undergo is very much increased. This fact is illustrated by Table 1, which gives a statement of the approximate service required from various structural and machine members.

Investigations have been made in recent years by Howard, Stanton, Basquin, Smith, Eden, Rose and Cunningham, Kommers, Mason, Moore and Seely, and others. The efforts of these investigators have been directed toward the study of moderin materials, refinements in methods of testing, and interpretation of results. The limits of actual tests have not been extended to modern requirements, and the problem still remains of obtaining test data for much longer endurance of fatigue than was contemplated by Wöhler. Under the most favorable conditions conceivable such data will be obtained very slowly, and meanwhile there must be faced the problem of determining safe stresses for very large numbers of repetitions by extrapolation from previous test results.

Table 1. Approximate service required of various members of structures and machines subjected to repeated stress.

Part of structure or machine	Approximate number of repetitions of stress in the "lifetime" of the structure or machine
Railroad bridge, chord members	2,000,000
Elevated-railroad structure, floor beams	40,000,000
Railroad rail, locomotive wheel loads	500,000
Railroad rail, car wheel loads	15,000,000
Airplane-engine crankshaft	18,000,000
Car axles	50,000,000
Automobile-engine crankshaft	120,000,000
Lineshafting in shops	360,000,000
Steam engine, piston rods, connecting rods and crankshafts	1,000,000,000
Steam-turbine shafts, bending stresses	15,000,000,000

MACHINES FOR TESTING FATIGUE STRENGTH.

Fatigue tests cannot readily be carried out with ordinary "static" testing machines. It is, of course, possible to repeat loadings on a test specimen in such a machine, but the process is very slow. Such a machine equipped with an ingenious automatic arrangement for applying and releasing load was used by Van Ornum in fatigue tests of concrete in compression, but the time required for even a hundred thousand cycles of stress was very great.

A very simple repeated-stress testing machine acts by the application and removal of a weight to the end of the long arm of a simple or compound lever, the specimen carrying load at the short arm. Such a machine was used by Berry in fatigue tests of concrete in compression. In a machine of this type the load must be applied slowly, else there will be inertia forces set up by the impact of the weight as it is let into place.

A common type of repeated-stress testing machine is one in which a calibrated set of springs resists the tensile, compressive, flexural, or torsional stress set up in the specimen, and the deformation of the calibrated set of springs gives a measure of the force or moment acting on the specimen. Fig. 1 diagrammatically illustrates this type of machine which was used by Wöhler and has since been used by many other experimenters. The Upton-Lewis machine is of this type and extensive use was made of it in torsion tests carried on by McAdam. This type of machine permits a fairly high rate of repetition of cycles of stress, and machines which have been run at 1,000 repetitions per minute have given results apparently trustworthy.

*Reproduced from the *Journal of the American Society of Mechanical Engineers*. A progress report of Committee on Fatigue Phenomena in Metals which is acting under the joint auspices of the Engineering Foundation and the Division of Engineering of the National Research Council.

The most common type of machine for reversed bending stresses uses a circular specimen acting as a rotating beam. This type was used by Wöhler, and also by many later investigators. Fig. 2 illustrates such a machine. The specimen is in form of a bar of circular section, to which bending stress is applied by weights. The specimen is rotated by means of a pulley. At any instant the outer fibers are subjected to a stress varying from tension on one side to compression on the other, and the fiber stress at any point passes through a cycle of reversed stress during each revolution. As shown, the specimen is loaded at two symmetrical points of the span, and between these two points the extreme fiber stress is constant for each element along the bar. This type of machine permits high speed of reversal of stress, speeds up to 2,000 r.p.m. having been successfully used.

British experimenters have used repeated-stress testing machines in which varying stress was applied to a specimen by means of the inertia of reciprocating parts. Fig. 3 shows such a machine, which can be used at high speeds. However, the speed must be very closely controlled, as the inertia forces vary with the square of the speed. Moreover, friction on the guides causes some slight uncertainty as to the magnitude of stress set up at each stroke of the crank.

A repeated-stress testing machine depending on centrifugal force to produce cycles of stress is shown in Fig. 4. It is evident that as the eccentric weights revolve the specimen will be placed alternately in tension and in compression. This machine has been used by J. H. Smith. Its characteristics are much like those of the inertia type; in fact, it is a special form of inertia machine.

A type of machine used by Arnold and later by other experimenters is shown in Fig. 5. In this machine a specimen is repeatedly given a certain deflection. Usually this deflection is sufficiently large to stress the material well beyond the yield point, and no very definite stress can be computed. This machine is used mainly for short-time tests.

Another short-time-test machine uses the repeated impact of a small hammer. The claim is made that impact loading emphasizes local flaws better than a load which is more gradually applied, and that it *indirectly* gives a better index of fatigue strength. Data, however, are lacking to prove or disprove this claim.

Various repeated-stress testing machines have been constructed in which the cycles of stress were set up by the action of an electromagnet energized by alternating current. Usually the stress was measured either by the deflection of a spring or by the deformation of a standard test bar attached to the specimen. The speed of such a machine, however, is usually so high that there seems to be some uncertainty as to whether the successive waves of stress pass through the specimen without interference.

While the microscope can hardly be classified as a testing machine, it has, nevertheless, been of such vital importance in studying fatigue phenomena that it may well be mentioned in this place. Space will not permit of a detailed description of the methods employed in the microscopic examination of metals, but the process involves polishing a small area of the metal, etching the surface with some reagent to bring out the lines of the crystalline structure and examining and photographing the surface through a microscope, the surface of the metal being illuminated by means of a reflected light.

THE PHENOMENA OF FATIGUE FAILURE.

A fatigue failure of a metal, whether it occurs in a test specimen or in a machine part, is characterized by suddenness, lack of warning, apparent brittleness of material, and, in many cases, a fracture with a crystalline appearance over a part of its surface.

This crystalline appearance led to the old theory that under repeated stress metal "crystallized," changing from a ductile "fibrous" structure to a brittle "crystalline" one. This theory, however, has been quite thoroughly demolished as a result of study of the structure of steel under the microscope. As revealed by the microscope the structure of all metals used for structures and machines is crystalline, any "fibrous" structure being caused by inclusions of non-metallic impurities (for example, slag in wrought iron). Microscopic examination of metals under stress shows no change of the general scheme of internal structure, but under sufficiently heavy stress there appears gradual breakdown of the crystals in the structure.

When a ductile metal is deformed cold, the first deformation occurs in the particular grains which either take the most stress or have the lowest elastic limit. Deformation takes place by the slipping of one portion of the grain with reference to other portions. This slipping is shown by the appearance of lines called "slip bands" or "slip lines" extending across crystals and indicating planes of cleavage. As the load is increased deformation proceeds and other slip bands are formed, the law being that the most easily deformable grains

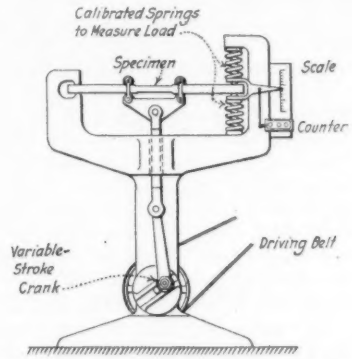


FIG. 1. A TYPE OF REPEATED-STRESS TESTING MACHINE

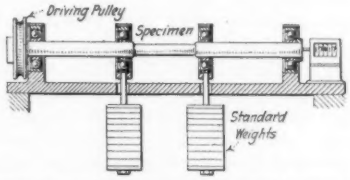


FIG. 2. TYPE OF MACHINE FOR DETERMINING REVERSE BENDING STRESSES

first show slip bands. Gradually the most favorable planes of slip are exhausted, and further slippage can take place only with the addition of more load.

The failure in ductile metals subjected to repeated stress takes place with substantially no general deformation. There is, however, considerable local deformation over microscopic areas, evidenced by the appearance of many slip bands on a polished surface of the metal after the application of repeated stress. These slip bands appear after a small number of reversals of stress with relatively large loads, and may not appear at all with slight loads. The slip bands may first appear either in the interior of a grain or at the grain boundary. As the number of applications of stress increases more slip bands appear, and those first appearing usually lengthen and widen. Under the microscope and with normal illumination the general surface becomes blacker as the number and width of the slip bands increase. In ductile metals fatigue failure is almost exclusively through the grains themselves rather than at the grain boundaries, and the first slip bands to appear do not necessarily form a part of the final path of rupture. Failure seems to take place by the uniting of slip bands into cracks. When the first grain develops a crack extending across its entire width, added stress promotes the extension of this crack into adjacent grains on both sides, although the orientations of these grains may be and usually are such that the crack must extend itself at an angle to that in the initial grain. The general tendency is for these

slip bands to follow the lines of cleavage of the particular grain in which they occur. Often incipient fracture is found in many grains adjacent to the final path of rupture, indicating that had rupture not taken place where it did, it would have soon taken place in some other adjacent part.

Such observations by means of the microscope indicate that *localized deformation* is the primary cause of fatigue failure in ductile metals, but it does not necessarily follow that the formation of one slip band under repeated stress will indicate eventual fracture if the loading is continued; one grain may appear to have a greatly reduced elastic limit because of in-

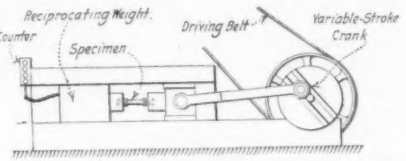


FIG. 3. BRITISH FORM OF REPEATED-STRESS TESTING MACHINE

ternal strains or peculiarly unfavorable orientation. It is not certain that there is a limiting load below which fatigue failure will never take place.

Materials classified as brittle have very little permanent deformation under static stress, and under repeated stress the progressive fracture of brittle material might take place, not by slipping within crystals, but by tensile fracture of crystals. There has been practically no study made of the fracture of brittle materials under repeated stress, and it would be instructive to have tests carried out on brittle amorphous materials such as fused silica and on brittle crystalline materials like marble or tungsten. It is gradually being recognized that the breaking load of a specimen is a complex matter, and depends, among other things, on the time of application of the load. Mere duration of static loading, however, does not have an effect at all comparable with repetition of loading in reducing the breaking load. It seems evident that the distribution of stress in some brittle materials is very much less uniform than in ductile materials, and that fractures in brittle materials start on areas of high stress, whereas in ductile materials the high stresses are relieved by local yielding. A more complete understanding of the mechanism of rupture in brittle materials would doubtless be of great value.

When the action of metal under repeated stress is considered from the view point of the internal strains and accompa-

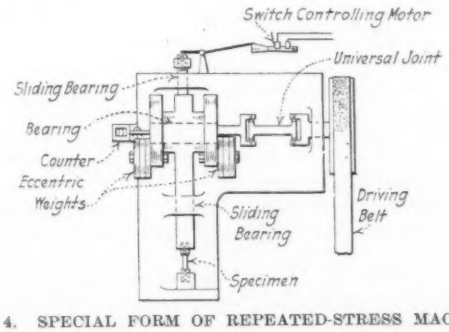


FIG. 4. SPECIAL FORM OF REPEATED-STRESS MACHINE

nying stresses in the material, a radical difference is seen in the behavior of material under static load and under repeated load. In a general way we may consider any structural or machine part as subjected to static conditions if the load on it is applied gradually and is not repeated more than a few hundred times; the part may be considered as subjected to fatigue if the load on it is applied, say, one hundred thousand times or more; and for intermediate conditions of loading the phenomena characteristic of both kinds of loading would be present.

We must look upon steel as filled with a multitude of minute flaws. These flaws are developed in the solidification of the material. In static testing, steel under stress of about half its ultimate strength passes into semi-plastic condition, in which there is a gradual flow of the material. Under such conditions the small flaws have almost no effect upon the flow or upon the static strength. When steel is loaded to moderate stresses the yielding is almost entirely elastic, but in general a small portion of it is inelastic, energy being taken up by the steel itself. If the specimen can be loaded a great number of times without heat loss its temperature will increase. If it is set vibrating in a chamber free from air it will stop vibrating in a short time, due to the absorption of energy. In such cases the stress-strain curve appears to be straight and the curve for the removal of the load may be practically identical with that for the application of load, but still these other effects show loss of energy in the steel itself.

This loss of energy is doubtless due to small displacements at these flaws, which are not reversible. Under alternate loadings these displacements are made back and forth. Energy is continuously being absorbed in the location of these small flaws, and it is perfectly natural that they should increase in size. We must look upon these extensions of the flaws as occurring in a great many parts of the steel. If the stresses are small the increased size of these flaws is practically negligible, but if the stresses are larger the increase is rapid, and later on in the history of the piece under test, very rapid, and

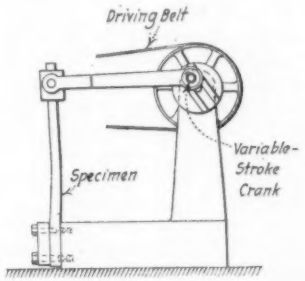


FIG. 5. SHORT-TIME REPEATED-STRESS TESTING MACHINE.

finally the strength of the piece is terminated when a sufficient number of these flaws have connected so as to form an area of very great weakness.

For static loads all the above is of little consequence with a ductile metal; but it is of consequence in the case of a brittle metal like cast iron, which has a remarkably low strength in tension in comparison with its compressive strength. Ductile metals may be considered as having a very high value for cohesion with a rather low coefficient of friction—or whatever corresponds to that—so that these metals begin to slide on diagonal planes without actual fracture under high local stress.

When a ductile material is loaded it may be subjected to stresses whose average values for small areas are not very different for parts that are a tenth of an inch apart; but there is a multitude of tiny spots whose fiber stresses are 2, 3, 4 or 10 times the average value. This holds so long as elastic conditions obtain. As the applied stress increases some of these stresses increase in like ratio, but not in like increments. At moderate applied stresses these special stresses reach inelastic conditions and slipping occurs. If the average stress is now entirely removed, we may assume that the unloading takes place in a similar manner. The small spots unload first in an elastic manner, but at a different rate than the remainder of the material. They will unload approximately at the same rates as they used in taking stress, namely, 2, 3, 4 or 10 times the normal rate. For the unloading they have about twice the range of stress that they had in the loading before inelastic action is set up. Some of them will reach the opposite limit and slip part way back again, while some of

them may not be subject to this return slip of inelastic action, but will retain in the unloaded state a stress distribution of the opposite kind. Either of these actions will give rise to hysteresis and to slight change of dimensions, usually, however, too small to be detected.

In all of the foregoing the main parts of the material have not been subjected to stresses which give inelastic action. If the loading is repeated without reversal, the spots that slipped on the first unloading will be subjected to further slipping both on loading and on unloading, but the areas that suffered no slipping on the first unloading should show no further inelastic action unless the loading is reversed. If the loading is reversed, however, all the particles that slipped in the first loading will slip on the reverse loading, so that with repetition a larger number of spots undergo this slipping action than is the case with loading which is not reversed. This explains the shorter life under reversed stress than under repeated stresses in one direction only.

If the fractural surface of a "rotating beam" specimen made of ductile metal and broken by repeated stress is examined, it is usually seen to be made up of two parts: (1) near the extreme fibers there is a dark surface with a dull, lusterless appearance, while (2) the remainder of the surface has a bright crystalline fracture. If these are examined more carefully it is found that their principal difference is in the size of the small flat surfaces that constitute the fracture. The center portion of the area has comparatively large surfaces, giving a crystalline effect, while the dull gray portion has very small surfaces of fracture.

An explanation of this is that the flaws in the outer portion of the surface have connected to form an annulus, whose rugged face is roughly at right angles to the axis of rotation. This has doubtless occurred slowly, and has started from many centers, thus giving the rough face. After this slow growth of flaws into an annular fracture has been accomplished the specimen has become very weak and the stresses have become so large at the fracture that they suddenly tear the metal in two on the natural surfaces of cleavage of the crystal grains.

The center portion of this fractured surface does not differ from the crystalline surface at the bottom of a cup in an ordinary static tension fracture, except that the crystalline surfaces are somewhat larger. This is to be explained by the fact that in an ordinarily tensile test the material at the fracture has elongated something like 100 per cent, so that the crystal grains have become of smaller cross-section and will naturally show smaller facets on fracture, whereas, in a fracture of the endurance specimen, the material has had no chance to elongate and the crystalline grains have their normal size, which will be shown in fracture. It is not the crystalline portion of the broken specimen which has failed primarily by repeated stress, but the dull portion. In the crystalline part of the fatigue fracture and in the crystalline part of the static tension fracture the failure seems to be of the same nature, namely, a failure in cohesion.

In considering the phenomena of fatigue failure it may be well to call attention to the fact that there is an intermediate type of failure of ductile material in which both plastic action and the development and spread of microscopic flaws are present. Such failures sometimes occur in staybolts, boiler sheets between rivet holes, and other parts occasionally subjected to very severe local distortion.

LOCALIZED STRESSES UNDER STATIC LOADING AND UNDER IMPACT LOADING.

When a machine member or structural part is loaded gradually a state of strain and accompanying stress is set up throughout it. In a general way the distribution of stress is similar to that given by the theory of elastic action which serves as a basis of our formulæ for computing stress and strain. There are, however, many deviations from this distribution due to non-homogeneity of the material and to irregularities in outline such as projecting corners, scratches and tool marks. When load is applied the general behavior of the piece as indicated by careful measurements of stretch, compression, twist, or flexure conforms to that required by the common theory of elastic action, but there are doubtless many localized strains which cannot be detected, even by the use of delicate micrometer measurements. It is to be recalled that in measuring strains it is necessary to use a gage line of considerable length, with the result that the observed strain is an average value along a relatively long line. The localized stresses, corresponding to these undetected localized strains, are not of any great importance under static load. When the load is increased to such an extent that a considerable portion of the piece is stressed beyond the elastic limit, the distortion of the piece increases abnormally and the piece may be considered to have reached its yield point. After this limit is passed the distribution of stress is much modified, and for parts made of ductile material the abnormal distortion at the yield point usually gives warning of structural damage before complete failure occurs.

Under impact loading, which is merely loading applied in a very short space of time, the action is somewhat similar to that under static loading, except that ductile material may offer a higher resistance to very rapid fracture than it does to fracture occurring gradually through a period of several minutes. Impact fracture, moreover, may emphasize somewhat the localized stresses set up at places where the structure of the material is non-homogeneous, or at places where there are sharp notches or deep scratches in the surface of the piece. Under slowly applied load there is opportunity for considerable adjustment and equalization of stress after the yield point is passed; under impact load there is probably less equalization on account of the rapidity of the action, and hence the localized stresses are higher and more effective in causing failure. This explanation of the action under impact is given here because repeated stresses also emphasize the effect of high localized stress, though for an entirely different reason.

TESTS AND CRITERIA FOR FATIGUE STRENGTH.

It was formerly the common opinion that the determination of the elastic limit of a material by means of a static test in a testing machine gave a reliable test for the fatigue-resisting qualities of the material, and that the material could withstand an infinite number of repetitions of stress lower than this elastic limit. Tests at various laboratories, however, have quite thoroughly disproved this idea, and have thrown grave doubts on the reliability of the elastic limit as an index of fatigue strength. The term "elastic limit" has always been rather loosely used, and covers several quite different stresses. The value determined for the elastic limit for any material depends on the sensitiveness of instruments used and the accuracy of plotting results, and the elastic limit as determined by such a test in a testing machine is determined by the average behavior of the material over a considerable length, while the process of fatigue failure may be going on over a section so small that it does not appreciably affect the readings of the measuring instruments used. In several laboratories comparative repeated-stress tests of different materials have shown higher fatigue resistance for the material with the lower elastic limit.

Bauschinger in his classic experiments showed that the elastic limits in tension and compression as determined by ordinary testing-machine tests were variable limits, their value depending on the treatment of the material during fabrication. He called such limits "primitive" elastic limits, and showed that when a specimen is subjected to gradually increasing range of alternating stress there are soon set up two elastic limits in the bar—one in tension and one in compression. He called these limits, which may have values widely different from the "primitive" elastic limit, the "natural" elastic limits, and the range between them the "elastic range." He also showed that a test specimen will stand several million repetitions of this elastic range of stress without failure, and proposed the "natural" elastic limits as indices of the

fatigue-resisting strength of the material. J. H. Smith has developed a somewhat simplified process of determining the elastic range. This elastic range seems a more reliable index of fatigue strength than the ordinary "primitive" elastic limit, but the reliability of indices of fatigue strength based on determinations of any elastic limit by testing-machine tests is open to question on account of the possibility that localized fatigue failure may be in progress without affecting the readings of the instruments used in static tests.

Wöhler used as an index of fatigue strength the "endurance limit" of material as determined from a series of fatigue tests with different intensities of stress. He used the method of plotting values of stress (S) against numbers of repetitions required for fracture (N) and determining by eye where this S-N curve became "practically horizontal." Other investigators have plotted values of S against values of $1/N$ or of $(1/N)^n$ and by extending the diagram till it intersected the axis of ordinates have determined an assumed endurance limit for an infinite number of repetitions of stress. Both of these methods involve enormous extrapolation of test data. Moreover, widely different endurance limits can be determined from the same test data by different methods of plotting values. The tendency to irregularity of test results under low stresses makes the decision whether the S-N curve is horizontal or slightly sloping downward one of very considerable uncertainty.

It has been proposed by various experimenters to compare the fatigue-resisting qualities of different metals by short-time tests with stresses well beyond the yield point of the material. Such tests are quickly and easily made. Under such stresses, however, the action of the material is partly a plastic flow. Such tests give good promise of determining fatigue strength and toughness under occasional overload for parts such as staybolts, which in their ordinary service are subjected to rather severe distortion, but it is not at all certain that such tests give a reliable index of resistance of machine parts under ordinary working stresses.

It has been proposed by various laboratories to compare the fatigue strengths of various materials by comparing their life under repetitions or reversals of some standard stress, usually less than the elastic limit of the material as determined by a static test. A somewhat similar standard proposed is to determine the stress which will cause failure under a given number of reversals. Standard stresses proposed for steel are 38,000 lb. per sq. in. (reversal) and 25,000 lb. per sq. in. (reversal). One million reversals has been proposed as a standard "life." These two types of test approach working conditions more closely than do the short-time, high-stress tests described above. However, they determine only one point on a S-N diagram for a material and do not indicate how fatigue endurance changes with change of stress.

A comparative study of fatigue strengths of various materials can be made from a S-N diagram plotted on logarithmic paper. Up to about 1,000,000 repetitions of stress logarithmic S-N diagrams fall quite closely along straight lines, and from the ordinates and slopes of these lines the behavior of materials under various intensities of stress can be studied. Tests may conveniently be made with stresses at about the yield point of the material, at stresses about 20 per cent lower, and at one or two intermediate stresses.

Various other possible tests have been proposed for determining the fatigue-resisting strength of a material, but no test has been proved to be of sufficient reliability to be accepted as a standard. A number of tests, however, seem worthy of experimental study.

The rate of dying out of vibrations in a "tuning fork" specimen of the material has been suggested as a possible index of fatigue strength. It is assumed that the gradual dying out of vibration is due largely to loss of energy spent in inelastic action in the material, and that such inelastic action is a measure of the fatigue weakness of the material. Test data are lacking to determine the value of this test, but it seems worthy of study.

Tests of magnetic permeability have also been proposed to locate internal flaws in the material and thus indicate its relative fatigue strength. The entire subject of the correlation of the magnetic and the mechanical properties of iron and steel is a promising field of investigation.

The rise of temperature under repeated stress has likewise been proposed as a measure of fatigue resistance. Theoretically, if a specimen is subjected to reversed elastic stress no change in temperature should take place, and it has been proposed to determine the endurance limit for metals at that stress which causes the first noticeable rise in temperature after some thousand or more reversals. A practical difficulty in using this test is to secure proper heat insulation for the specimen. This test seems worthy of study, however, especially if employed in an inertia type of testing machine (see Figs. 3 and 4).

The detection of the appearance and growth of "slip lines" in a specimen subjected to repeated stress gives some promise of furnishing a reliable test for fatigue strength. Slip lines appear long before fracture occurs, and if their appearance or the rate of their spread can be shown to be an index of fatigue strength it seems possible that a feasible laboratory test may be devised. The search for slip lines over any considerable area would, however, be very tedious.

Impact tests, usually on notched bars in bending, have been proposed as an index of fatigue strength. The actions under impact failure and under repeated stress are very different, the first giving a sudden break of the entire cross-section of the specimen, and the second a gradually developing fracture. Both failures, however, seem to be affected by localized flaws or irregularities in outline, and though no definite correlation between fatigue strength and strength to resist impact has been established, yet such tests are worthy of study. Repeated-impact tests have also been proposed to determine fatigue strength, but whether such tests have any advantage over short-time tests under non-impact loads is not known.

In all tests to determine fatigue strength it is of the highest importance to secure uniformity of surface finish between the different specimens to be compared. Probably this can best be done by polishing the surface of the specimens where failure is expected.

There is today no short-time test accepted as a standard test for fatigue strength; but the development of such a test, and the establishment of its reliability, would unquestionably be of very great service to testing engineers.

LOCALIZED STRESS AND ITS INFLUENCE IN PRODUCING FATIGUE.

The ordinary formulæ and methods of analysis used in computing the fiber stress in a machine part or structural member are based on the assumption that the material is homogeneous throughout, and that the cross-section of the member is either constant or that it changes its dimensions so regularly and gradually that there is no appreciable localized fiber stress at sections of rapid change. For structures and machines of ductile material subjected to not more than a few hundred loadings, such assumptions are reliable, because localized stresses do not appreciably affect the general deformation of a member, nor do they under ordinary working conditions cause trouble before the member has been subjected to some thousand or more repetitions of load. For nearly all parts, however, high localized stresses are present. Internal flaws may cause such localized stresses. This is shown by mathematical analysis of stress in plates with holes in them and by direct experiment on such plates. External irregularities of outline may cause localized stress. Under bending or twisting a member with a sharp reëntrant angle in its outline theoretically develops an infinite stress at the root of the angle, and actually both mathematical analysis and direct experiment show that very high localized stress may be caused by sharp grooves or

scratches on the surface of a machine part or structural member.

It has been stated above that for parts subjected to a few loadings localized stresses are not of great significance. The case is quite different, however, for parts subjected to thousands of loadings. High localized stress may cause a crack to start, either directly or by "cold-working" the material where the localized stress exists until the material becomes brittle. This crack forms an extension of the discontinuity of the material which caused it, and under repeated stress tends to spread still more rapidly. This tendency is illustrated by the action of a piece of plate glass in which a crack has started. In most cases under any repetition of load the crack spreads, and will cause final fracture of the glass. A fatigue failure under repeated stress is a progressive failure. This spreading of cracks to cause failure explains why under fatigue even ductile materials snap short off. Failure does not involve plastic flow of considerable masses of metal, but only of microscopic masses near the crack, and final fracture comes suddenly just as if the member were cut half off by means of a saw cut and then bent. The importance of avoiding localized high stress in members subjected to repeated stress can hardly be overemphasized. Homogeneity of internal structure, smoothness of external surface, and avoidance of sudden changes of cross-section may be more important in the construction of machine parts subjected to repeated stress than is high static strength of material.

Shoulders of crankshafts and of axles, keyways in shafts, screw threads, and rivet holes are examples of locations where high localized stress is liable to occur.

RELATION BETWEEN MICROSCOPIC STRUCTURE AND FATIGUE.

A very large field of investigation and one in which very little systematic work has been done is the study by means of the microscope of fatigue failures in various characteristic structures of metals, especially steels. The following paragraphs are given as a summary of the theory held by present-day metallographists of the relation of microstructure of metal to its fatigue strength. Many of the details of this theory, however, lack adequate experimental verification.

Annealed steel consisting of ferrite (pure iron) and cementite (iron carbide, Fe_3C) seems to increase in resistance to fatigue with the increase in carbon content, especially when the cementite is present in the form of plates as in lamellar pearlite and as long as the cementite does not surround the grains of pearlite. When the cementite is spheroidized, the elastic limit is greatly decreased and probably the resistance to fatigue is also decreased. As a structural material, therefore, a steel with considerable carbon in the form of spherical globules of iron carbide would have practically no advantages over wrought iron. When, however, the iron carbide is in plates it seems to have a marked effect in raising the elastic limit, and probably increases the resistance to fatigue. We would also expect that complete and large networks of ferrite would lower fatigue resistance.

The same arguments regarding grain size of single constituent metals hold to a certain extent for two component alloys. For example, such experimental evidence as is available indicates that the sorbitic structure in steel is the one which resists fatigue best. This structure is supposed to represent an extreme refinement of grain in which the particles of iron carbide are very small, and hence the particles of ferrite must also be very small. It is true that some of the iron carbide may be in solution in the iron, but it is more probable that the mechanical properties observed can be accounted for by an extreme reduction in the size and by the dispersion of ferrite and cementite particles. When these globules are made larger by heating to a higher temperature than that at which the sorbite was formed, granular pearlite results with reduced fatigue resistance.

When a high-carbon steel is quenched from above the critical range to form martensite, the metal becomes extremely brittle. The normal path of static rupture in brittle martensite is at the old austenite (solid solution of Fe_3C in gamma iron) grain boundaries. The path of rupture in fatigue has, so far as is known, not been ascertained. From certain tests on the resistance to fatigue of chrome-vanadium steel after various heat treatments, Dr. C. M. Olmstead of the C. M. O. Physical Laboratories, Buffalo, found that the steel in the martensite state, that is, as quenched, had a very much lower resistance to fatigue than after reheating to about 1,100 deg. fahr. The maximum resistance to fatigue occurred by quenching and reheating to 1,000-1,200 deg. fahr. (538-648 deg. cent.), and there was very little difference between the specimens tempered at 1,000 deg. and at 1,200 deg. There was a marked difference, however, between these and the samples tempered at lower tempratures or those not tempered at all. This is the heat treatment that is commonly given to automobile parts which must withstand fatigue stresses, and which may be subjected to shock. The tempering of springs is done at a little lower temperature, but it is not certain that the spring structure is the one having the highest resistance to continued repetition of stresses.

It seems from the above that martensite is not a suitable material to withstand fatigue stresses, and that some intermediate structure between martensite and the annealed or normalized structure will have the maximum resistance to

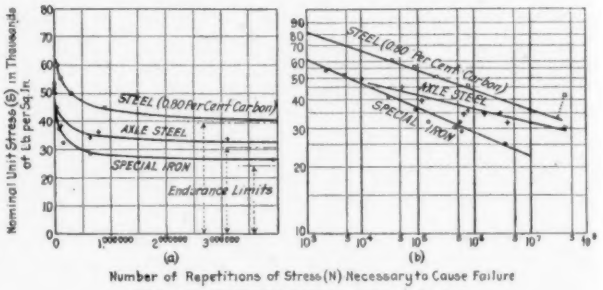


FIG. 6. STRESS-STRAIN DIAGRAMS

fatigue. This structure is called the sorbitic structure and corresponds to that used in automobile springs and other parts of automobiles which must resist fatigue and shock stresses.

FORMULÆ FOR DESIGNING PARTS SUBJECTED TO REPEATED STRESS.

All formulæ which have been proposed for designing parts subjected to repeated stress depend upon extrapolation from test results and should therefore be regarded as tentative. Their use is justified only on the ground of necessity. Parts must be designed to resist repeated stress, and even formulæ derived from a confessedly inadequate experimental basis seem better than mere guesswork. Two types of formula have been used.

In many discussions of data of repeated-stress tests, it is assumed that there exists some definite "endurance limit," that is, some stress, greater than zero, which can be repeated an infinite number of times without causing failure of the material. If such a limit exists it is certainly lower than the elastic limit of the material as determined by static tests, for actual failures of materials have occurred under repeated nominal stresses as low as one-quarter of the elastic limit as determined by a static test. Examination of test data indicates that the endurance limit is an assumption rather than a proved fact. It is usually determined by plotting a diagram with stresses as ordinates and number of repetitions producing failure as abscissæ and estimating the stress for which the diagram seems to become horizontal. Various other methods have been proposed, but all involve this assumption.

In 1910 a paper presented before the American Society for Testing Materials pointed out that an examination of the results of numerous series of repeated-stress tests indicates that

for nearly all the range covered the law of resistance to repeated stress may be expressed by the equation:

$$S = KN - m \quad [1]$$

in which S is the maximum unit stress developed in the test piece, N the number of repetitions of stress necessary to cause failure, and K and m are constants depending on the material and somewhat on the manner of making the test. This is known as the "exponential equation for repeated stress."

Another form of expression for the above equation, and frequently more convenient, is:

$$\log S = \log K - m \log N \quad [2]$$

If the logarithms of S and N are plotted, or if the values of S and N are plotted on logarithmic cross-section paper, Equation [2] is represented by a straight line. In Fig. 6*a* ordinary coördinates are used, but in Fig. 6*b* the coördinates are logarithmic. For large values of N the exponential equation gives in many cases values of S smaller than the observed values; in other words, the exponential formula seems to err on the side of safety.

It will be noted that the use of the exponential formula involves the assumption that any stress if repeated often enough will eventually produce failure of the material. Thus while both the endurance limit and the exponential formula are based on extrapolation from known data, the exponential formula seems to be an assumption on the safe side. The working stresses as developed by the two methods do not differ greatly except for members subject to more than ten million repetitions of stress. Above that number the exponential formula requires lower working stress, but even then the stresses given by the exponential formula are not impracticably low.

While nothing but tentative formulæ can be proposed now, some features which a satisfactory formula for fatigue strength should include may be noted. It is probable that such a formula for any material will not depend on ordinary static qualities of the material such as elastic limit or tensile strength. It may depend on some form of elastic limit determined after the material has been put in a "cylic" or "normalized'" state by a number of reversals of stress. Such a formula will quite probably contain factors dependent on the surface finish of the part and upon the uniformity and regularity of its crystalline structure. It will contain a factor dependent on the range of stress during a cycle. Such a formula may contain a factor dependent on the probable number of repetitions of stress which the part may be expected to withstand during a normal period of service, or the result may be an "endurance limit"—a stress which the part is capable of withstanding so many times that even for modern high-speed machinery the number of repetitions may be regarded as infinite.

SPECIAL SUBJECTS NEEDING INVESTIGATION.

Long-Time, Low-Stress Fatigue Tests of Metals. It is not known today whether machine or structural parts can withstand an infinite number of repetitions of any stress, however small. It is not known what share of blame for the occasional failures of test speciments or of actual parts in service under low nominal stress should be attributed to weaknesses in the metal structure to localized damage to the surface with resulting increase of localized stress over nominal stress, or to "harmonics" of high stress due to interference of waves of stress traveling through the part. There should be undertaken an extensive series of long-time, low-stress tests on typical irons, steels, and other metals. It is doubtful whether any series of tests can settle the question of the existence of an endurance limit, but a considerable amount of test data for endurances up to, say, 100,000,000 repetitions will give a better basis for working formulæ than is now available.

Study and Comparison of Different Testing Machines for Fatigue Tests. Different testing machines for determining fatigue-resisting qualities do not always give consistent results. A series of tests of samples of several typical metals run on various testing machines should give some indications of the reliability of various types of testing machines and perhaps enable correlation to be made between tests on different machines. For all series of fatigue tests careful chemical and microscopic tests of the material should be made to insure uniformity both of chemical content and of structure. Careful tension, compression, and torsion tests should also be made so as to insure uniformity of static strength qualities, and to give data for the study of correlation between static strength and fatigue strength. Short-time, high-strain, repeated-stress tests and impact tests should likewise be made to give data for the study of correlation between toughness, impact resistance and fatigue strength. All test specimens should be prepared with great care and surface conditions be kept as uniform as possible. It appears that this uniformity could be best secured by giving the surface a high polish.

Relative Importance of Surface Condition and Structural Characteristics as Shown by the Microscope. It seems practically certain that fatigue fractures may be started either at a surface imperfection or at an internal flaw, such as a "snowflake" or a "transverse fissure." The importance of these two types of defect might well be the object of experimental study. In connection with such a study there should be a study of methods of detecting internal flaws, such as deep etching, and a study of methods of indicating the degree of perfection of surface finish.

Effect of Grain Size of Metal on Fatigue Strength. On this subject Rosenhain says:

"The question then arises whether the increased size of crystals produced in a simple metal by prolonged heating is injurious or otherwise, so far as the useful properties, and more especially the mechanical properties, of the metal are concerned. There can be little doubt that within reasonable limits the mechanical properties of a simple metal are better the smaller the constituent crystals of which it is built up. Under the tensile test, coarseness of structure usually results only in a slightly lowered yield point, while the ultimate stress and the elongation are little impaired, although the reduction of area at fracture is sometimes markedly less. On the other hand, under both shock and fatigue tests, a coarse structure, even in a simple metal, gives unsatisfactory results."

Tests and service records quoted by Jeffries and by Ruder tend to confirm this opinion in the case of copper. Fine-grained copper is very much more resistant to repeated stresses than coarse-grained copper. Also if the elastic limit of fine-grained metals is determined by delicate instruments, it is generally found to be greater than that of the same metals in the coarse-grained state. Systematic tests should give us a firmer basis for conclusions in this important phase of fatigue phenomena.

There have been found no records of microscopic analyses dealing with the path of rupture under repeated stress in steels having various structures from martensite to the normalized state. A study of the path of rupture and the manner of rupture in these samples would be most interesting.

Development of Special Tests for Fatigue Strength. At present there is no short-time test for fatigue strength which has been proved to give reliable results. Some tests which give promise of usefulness are:

1. The Rise-of-Temperature Test used by Mr. Stromeyer. In this test the highest reversed stress which a specimen can stand without appreciable rise of temperature is taken as an index of fatigue strength.

2. The Development of "Mechanical Hysteresis." If a fatigue failure is in progress in metal subjected to repeated stress, very small amounts of energy are lost during every cycle of stress. The energy lost during each cycle may be too small to measure, but after some hundreds or thousands of cycles the cumulative effect of the losses may become appreciable. This loss may appear as a "loop" in the stress-strain diagram for a complete cycle of stress, and this indication may be detected at a comparatively early stage of the

fatigue failure. Dr. Stanton of the British National Physical Laboratory has made some experimental study of this development of "mechanical hysteresis," as this loss of energy is called. It is possible that mechanical hysteresis may be studied by the dying out of vibrations set up in a test piece, as has been proposed by Boudouard.

3. Magnetic Testing of Steel for Fatigue Strength. The structural damage done while a progressive fatigue failure is occurring may, possibly, be detected and measured by the change in magnetic permeability of the steel. Burrows, Dudley, and Sanford have done some experimental work on this subject, and magnetic analysis seems worthy of study as an index of fatigue strength.

4. Impact Tests and Repeated-Impact Tests. Although the action of metal under impact is very different from its action under repeated stress, yet both impact and repeated stress seem to emphasize local irregularities and imperfections of surface or structure. It may be that a repeated-impact test may be devised which will give a reliable measure of fatigue strength, and which will do so in a comparatively short time. Such tests seem worthy of study, though their value as tests of fatigue strength cannot be said to be established.

It is believed that the foregoing paragraphs outline fundamental investigations, many of which should be undertaken at an early date. Experimental study of typical metals under long-time, low-stress tests; study by means of the microscope of the phenomena of fatigue failure in metals of various crystal structures; and study of reliable test methods of determining fatigue strength constitute, in the opinion of the committee, the fundamental line of research in fatigue phenomena. Once such fundamental tests have made fair headway, especially the determination of a reliable test for fatigue strength a large number of problems call for study.

A TRIGONOMETRIC COMPUTER.

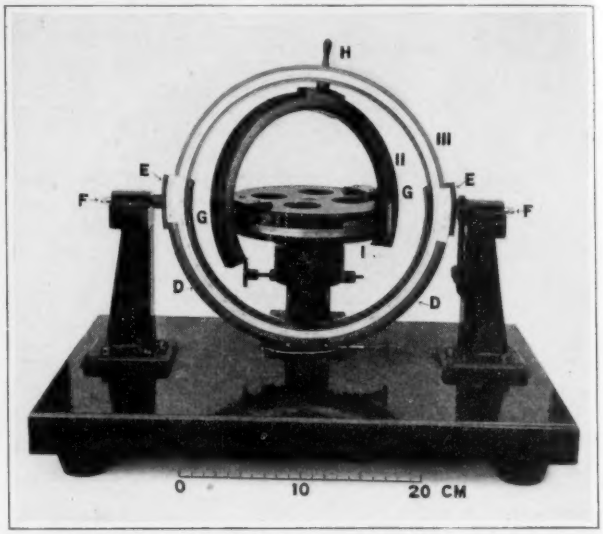
By F. E. WRIGHT, Geophysical Laboratory, Carnegie Institution of Washington.

THE solution of spherical triangles by the logarithmic computation of trigonometric formulas is at best a time-consuming process, especially if there be many such triangles to solve. In case high precision is required no other method is available; but if only approximate results are desired, graphical methods may be used, such as an exact projection net; of these the stereographic net published by G. W. Littlehales[1] is the most accurate and furnishes results correct to about 2′ of arc under favorable conditions. If the results are to be correct within one-half minute of arc graphical methods are not adequate and recourse must be had either to computation or to some mechanical device of high precision.

In crystallographic work the degree of precision is of the order of magnitude of ½′. In the measurement of the changes in crystal angles with temperature the position of each crystal face is determined on the two-circle goniometer by means of two angles (polar distance and azimuth). Having given the position-angles of any two faces, the angle between them can be found by the solution of a spherical triangle.

In 1913 the writer had occasion to solve many triangles of this type, and to save time had a mechanical computer constructed in the instrument shop of the Geophysical Laboratory. This instrument has proved to be satisfactory in practice for the solution of oblique spherical triangles in which three of the angles are given and the value of any one of the three remaining angles is sought with a precision of about half a minute. The computer was designed for, and functions best in, the solution of the problem; given two sides and the included angle of a spherical triangle; find the third side.

Description of Instrument.—A photograph of the instrument is reproduced in the accompanying engraving. It consists essentially of three concentric graduated circles which can be inclined at different angles one to the other. The inner circle I is horizontal and can be rotated about a vertical axis. The outer circle III fits in the semicircular groove *D* and is free to turn in this bearing, the angle of turning being read off on the vernier at *E*, *E*; the circle in its bearing can also be rotated about the horizontal axis *F*, *F*. The intermediate circle II is not a complete circle and is attached to the circle I by the horizontal axis *G*, *G*, and to the circle III by the axis *H*. The angles of rotation and revolution of these circles can be read off on appropriate verniers. The circles are equipped with clamp screws and slow-motion devices for the accurate setting of angles.



INSTRUMENT FOR COMPUTING SPHERICAL TRIANGLES

The following steps are taken to solve the problem: given two sides *a*, *b*, and the included angle *C* of a spherical triangle; desired the third side *c*.

Set the three circles at right angles to each other—all verniers reading 90°. Turn circle III about the horizontal axis to the position where it includes the angle *C* with the horizontal circle I (angle read off on the vernier of circle II). Turn circle II in its bearing until axis *H* includes an angle *a* with the axis *F*, *F*; turn horizontal circle I about its axis until axis *G*, *G* includes the angle *b* with the axis *H*. The angle *H-G* is then the desired angle *c*. The entire operation requires about one minute and is simple and readily checked.

The instrument is necessarily one of high precision, and first class workmanship is required to produce a satisfactory computer. In its construction care was taken to include adequate adjustment facilities such that the instrument can be readily adjusted in case of wear. The instrument is mounted on a heavy cast-iron base.

[1] Altitude, azimuth, and geographical position. J. B. Lippincott Company, Philadelphia, 1906.

ELECTRIC POWER FROM TIDAL CURRENTS.

TESTS carried out in the River Mersey with the Clarkson tidal turbine have shown that electrical power can be obtained from tidal currents at an estimated cost of less than a penny per unit.

The turbine consists of rows of buckets or paddles attached to endless chains, these running over sprockets mounted on a floating framework. There is thus a lower row of buckets immersed in the water, and an upper row out of the water traveling in the opposite direction. It is the pressure of the current acting on the buckets which causes the sprocket shafts to rotate, and so enables a dynamo or other apparatus to be driven. By the use of reversible mechanism, the turbine may be adapted for generating energy equally well on an ebbing or a flowing tide.—Abstracted by *The Technical Review* from *Practical Engineer*, Nov. 27, 1919.

Photo-Micrography Without a Microscope*

Simple Apparatus for Low Power Magnification

By G. Ardaseer

WITH low-power photo-micography—say, up to x 12—a microscope is not generally necessary, and any photographer who possesses a short-focus lens of about 3-inch focal length, and a camera with long extension, can set about doing quite successful work. The writer used for such purposes a Voigtländer Collinear of 70 mm. focal length—say, 2 4/5 ins.—and with a triple extension half-plate camera of 23 ins. when fully racked out he gets a magnification of x 7 without any additional extension device. The extensions are readily calculated from the formula $(M + 1) f =$ distance between ground-glass screen and, for convenience, lens diaphragm, where M is the number of desired magnification and f the focal length of the lens.

Consequently for	x4	the extension should be		14″
"	" x5	"	"	16 4/5″
"	" x6	"	"	19 3/5″
"	" x7	"	"	22 2/5″

Of course, with a lens of shorter focal length, such as an Aldis 2 in., the magnifications will be greater with the same extension.

To rig up the apparatus it is best to have a base-board, along the centre of one side of which a line is ruled lengthways. This simplifies centering the light and the object. The latter is held in some kind of holder, which will allow it to be adjusted to the axial line of the lens, and the illuminant is also adjusted to the same line. The diagram (Fig. 1) will indicate what is meant. AB is the baseboard, CD the camera, F, a tubular extension to fit camera and take lens L, H the slide holder, shown in detail in Fig. 2, and Z the illuminant. The tubular extension used by the writer consists of a piece of a stout cardboard tube—originally that in which bromide paper was packed—about 6 ins. in length and 2½ ins. diameter, and cut off accurately square; one end glued into a wooden camera front-piece and the other end fitted with a wooden disk with central hole to take the lens flange. It is important that the lens axis should be truly horizontal, and care must be taken to keep the disk end square with the tube. The object holder must have a hole about 1½ in. cut, but with its center exactly level with the height of the lens center above the base board. The holder can be fastened to the base board, or its base may be weighted to give rigidity. The light—the writer uses an inverted incandescent mantle—slides upon a rod on a heavy square base. If runners are attached to the base board, between which the holder and light-standard can slide, matters are made easier in adjusting the illumination. The camera is clamped to the base-board, and the whole arrangement is such that the center of the focussing screen, the center of the lens, the hole in the holder, and the light are in one straight line. There is a small ledge, LL (Fig. 2), on the holder on which to rest the slide, and two curved pieces of watch spring, SS, are screwed upon it to maintain the slide in a vertical position.

A penciled cross is marked on the ground-glass focussing screen at the intersection of its diagonals. The light is centered by focussing it on to the screen and moving it up or down or sideways until the image of the mantle is central with the cross. A piece of cardboard 3 ins. by 1 in., with a small hole in the center, is placed in the holder, with this hole central to that in the holder, and the same focussing and adjustment of the holder is to be observed. The object—say, a section of wood—is placed in position, focussed first by racking out the front of the camera and a final sharp focussing—seen best through a focussing glass, set to give a sharp image of the penciled cross on the ground glass—is effected by racking the back of the camera in or out until every detail is sharp. The light is cut off, preferably by interposing a piece of black card against the lens and between it and the object. The dark slide is inserted, the shutter withdrawn, sufficient time allowed to admit of all vibration ceasing, and then the card withdrawn and exposure made. The card is then replaced and the shutter closed. In many cases where the object is colored a color filter is almost a necessity, and a small holder for it, somewhat similar to the object holder, can easily be improvised. The filter should be placed close to the object (F in Fig. 1) and between it and the light. For mounted insects—generally of a yellowish color—a K3 filter is very useful. The Wratten series of M filters, although intended for M panchromatic plates, are almost essential for successful results with other plates.

For opaque objects the light or lights are placed at the side of the camera, but behind the lens, so that no direct light falls into the lens, and sometimes a couple of lengths of magnesium ribbon burned one on each side will give excellent results. In fact, the procedure in this case is similar to that of copying. In a short article minute details cannot be entered upon, but there is one point, exposure, which is most important. Insufficient exposure is fatal to success, and the judicious waste of a few plates, in the sense of two or three strip exposures on one plate, will do much to give an idea of

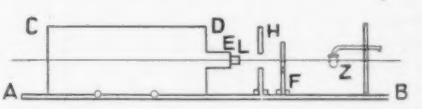


FIG. 1.

FIG. 2

the correct time to expose. This, too, is governed to a large extent by the color of the object, yellow, red, or brown objects requiring a very long time as compared with white, grey, or blue.

When focussing with the focussing glass it is very convenient to cement one or more microscope cover glasses with Canada balsam to the ground-glass side of the screen, and to focus the aerial image so produced. The writer, however, generally uses a focussing screen of his own make, as described by him in the *Journal* of June 27 last. He feels sure that any photographer who tries this method of low-power work will not stop there, but will desire to have a microscope as well, and wed it to the camera.

*Reprinted from *The British Journal of Photography.*

IMPROVED WEHNELT INTERRUPTER.

A NEW form of Wehnelt interrupter was exhibited by Mr. Newman at the meeting of the Physical Society on Dec. 5 last. Owing to the rapid disintegration of the platinum wire and because the current required for the working of the cell is large, the Wehnelt interrupter is not generally used. In the modified form, a plate of aluminum, having an area of 50 sq. cm. is substituted for the lead plate, the other electrode being platinum wire sealed in a glass tube. The electrodes are immersed in a saturated solution of ammonium phosphate made alkaline with ammonia. The interrupter works equally well with direct or alternating currents. The minimum potential difference required is 18 volts, but the frequency of the interruptions increases with the applied voltage.—Abstracted by *The Technical Review* from *The Chemical News*, Dec. 5, 1919.

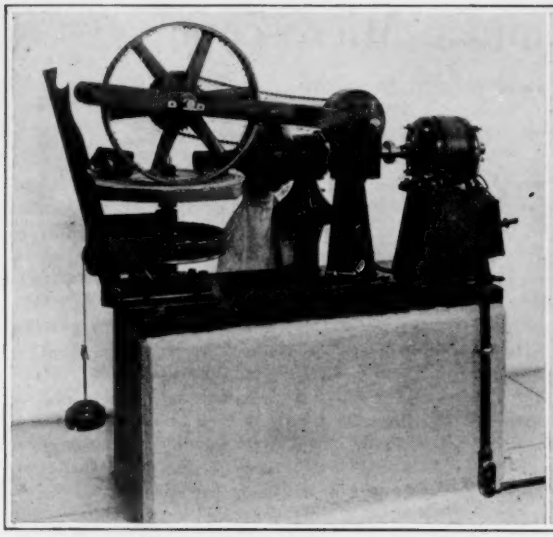


FIG. 1. WEARING TEST MACHINE AS USED AT PRESENT

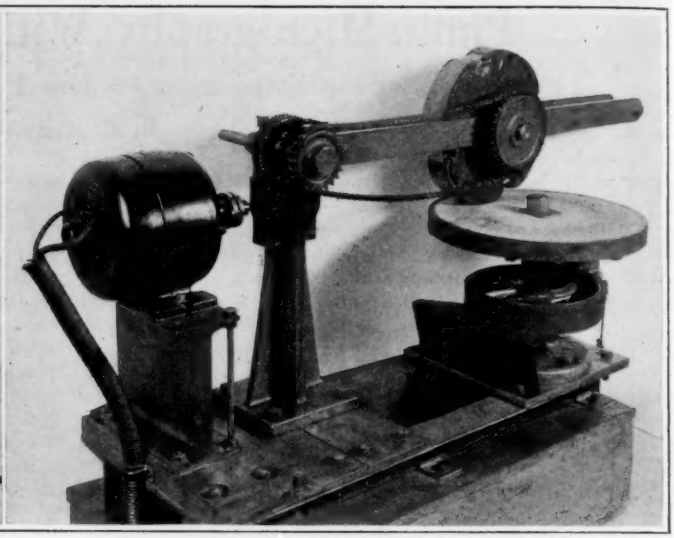


FIG. 2. WEARING TEST MACHINE AS FIRST USED

Measuring the Relative Wear of Sole Leathers*

Results Obtained with Leather from Different Parts of the Hide

By R. W. Hart and R. C. Bowker

THE quality of sole leather is affected by many factors, such as the breed of the animal, its mode of life, the time of killing, the method of preserving the hide, and the kind of tannage. A very important factor which influences the durability of any particular sole is the part of the hide from which it is cut. It is a difficult problem to measure the wear of sole leather and generally it is accomplished by actual service tests on individuals. Such a method takes considerable time, and the value of the results obtained is often uncertain on account of the many uncontrollable variables occurring in the types of service and among the individuals wearing the soles. The development of a simple method for quickly determining the durability of sole leather seemed desirable, and this paper discusses a laboratory apparatus designed for this purpose and also presents the results of tests made to date to determine the relative wear of leather from different parts of a hide.

WEARING-TEST MACHINE.

A machine has been developed at the Bureau for testing the durability of sole leather with the idea of subjecting the leather to shearing action during the wear similar to that occurring in service on shoes and at the same time accelerating the actual wearing away of the material so that an indication of the durability of the specimen might be obtained in about 24 hours. The machine as first designed (Fig. 2) embodied a cam of clover-leaf shape, to which the samples were attached, and which rested on a horizontal disk having an abrasive surface of cement. The difficulties with this design were that the samples were submitted to a bumping action which caused the wear of each sample to be so localized that it was often worn through on one end before the other end showed appreciable wear, that no means was provided for removing the material worn away, and that the abrasive material soon wore smooth which caused a longer time to be necessary for a test. The machine (Fig. 1) as later developed and as now used is described as follows:

A wheel of 15-inch diameter carries on its face 12 test pieces. The wheel revolves at the rate of 30 revolutions per minute about a horizontal axis with its bearings in two parallel metal bars which are pivoted at one end, the other end being free. The wheel carrying the weight of the bars (and any additional weight that may be suspended from their free ends), rests on a horizontal disk of 16-inch diameter, the point of contact being 5½ inches from the axis of the disk. This disk has a surface of carborundum, and rotates about a vertical axis on which is a brake wheel provided with a brake strap, by means of which any desired resistance to rotation may be secured by the application of dead-weight. The wheel is driven by a chain and in turn drives the horizontal disk with which the test pieces are in contact. The apparatus is designed with the view of subjecting the test piece to (1) a driving (shearing) action under pressure, and (2) a slight abrasive action resulting from the circular path of contact between the wheel and disk. The conditions of pressure and shear may be adjusted as desired. A circular brush is shown resting on the carborundum disk. This brush in connection with a small exhauster tends to keep the surface of the wearing disk clean.

A test usually consists of 40,000 revolutions of the wheel which corresponds with 40,000 steps, or approximately 40 miles of walking.

The substitution of a wheel for the cam eliminated the bumping action but retained the shearing action and resulted in a more even and smoother operation. The use of a wheel allowed more specimens to be tested at one time, the entire surfaces of which were subjected to the wearing action. By using carborundum for an abrasive, a material was obtained which did not become dull or smooth quickly and which could be resurfaced with an emery-wheel dresser.

A small suction fan and circular brush were added to the equipment in order to remove the dust caused by abrasion. These improvements permitted the wearing conditions to be more uniformly maintained.

METHODS.

Sole leather is generally sold in the form of bends. A bend is a half of a hide with the shoulder and belly portions trimmed off, the remaining portion being suitable for soles.

*Technologic Paper No. 147 of the Bureau of Standards.

In the tests conducted samples of leather from different locations on a bend were used to determine their relative durability or resistance to wear. When a whole bend was tested the general scheme was to divide it into blocks, as illustrated in Fig. 3. Each block was stamped with a code number, which fixed its location on the bend. When using the clover-leaf-shaped cam for holding the samples, test pieces approximately 24 by 5 cm. were required and they were attached to the cam by a clinching device. Test pieces for use with the wheel were about half as long and were attached by means of four countersunk screws. In either case the samples were

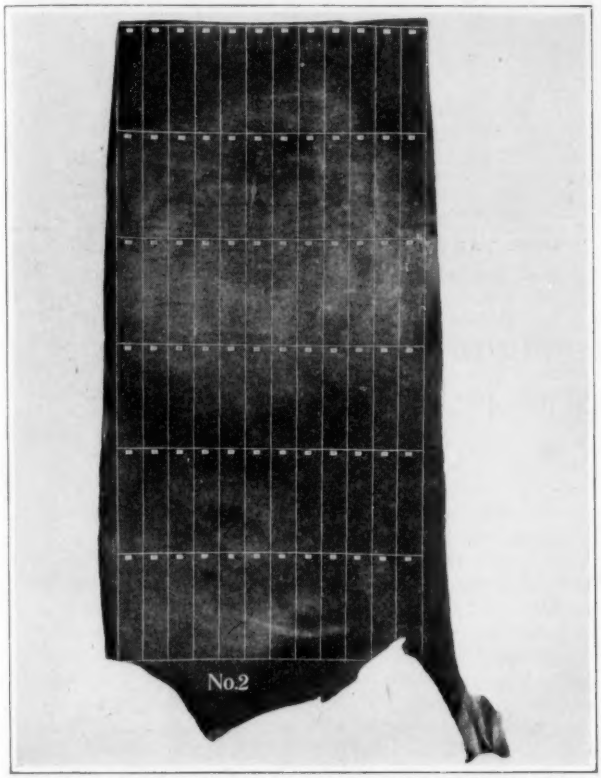


FIG. 3. A BEND MARKED OFF FOR MACHINE WEARING TEST

first weighed and then placed on the machine. After the test was completed the samples were again weighed and the loss in weight determined. The relative durability was obtained by determining the loss in volume from the loss in weight and the specific gravity. The sample showing the greatest loss in volume was considered as the least durable.

A small sample adjacent to the test specimen was used in determining the specific gravity. Since only the grain portion was worn away during the test, it was thought desirable to use the specific gravity value for the grain portion only. Accordingly the flesh portion of the sample was removed and the grain portion was then coated with cellulose nitrate to render the sample water-proof. The determinations were then made using a direct-reading gravitometer (Fig. 4).

CONCLUSIONS.

The results of these tests show that the machine indicates a decided difference in the wearing quality of leather taken from different parts of the hide, the portion near the back and over the kidneys having the best wearing quality and those portions near the belly edge, shoulder end, and extreme butt end having considerably less durability. These indications are in accord with the opinion and experience of many tanners and leather manufacturers. The results obtained on the machine in Test No. 4 also agree quite closely with those obtained in service tests.

In view of these facts it seems reasonable to believe that the machine may properly be used to indicate the relative resistance to wear of different leathers.

Owing to limitations of space the description of the series of tests with the two machines are omitted.—EDITOR.

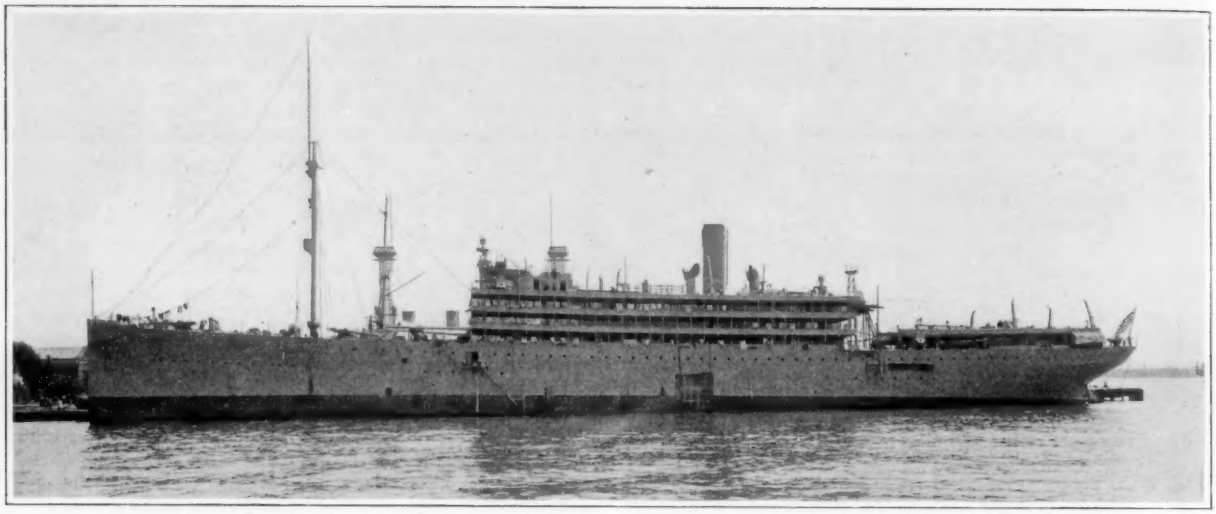
MANUFACTURE OF BUILDING STONE OUT OF CINDER OR SLAG.

THE present scarcity of building material has led to a new form of industry in Germany. At some large gas-works, notably at Heidelberg, Fürth, and Stuttgart, and other works where cinder or slag is produced, the manufacture of artificial building stone has been undertaken.

The stone is produced in blocks of a convenient size, usually 10 by 12 by 25 centimeters. It is formed of a definite mixture of cinder and cement, with either sharp sand or limestone. Its resistance varies, according to the composition, from 20 to 50 kilograms to the square centimeter. Thus 1 cement to 8 cinder gives a resistance of 205 kilograms, while 1 cement to 6 cinder and 2 sand gives a resistance value of 51.5 kilograms. Commonly adopted proportions are: 8 parts of cinder sifted to 10 mm. size; ¾ parts cement; and ¼ limestone, which give a resistance of about 30 kilos, and sufficient for the walls of ordinary buildings.

Only such cinder is suitable for this manufacture that has lain in the waste heap for a considerable time. Chemical action takes place in waste heaps, which action must be left to work itself out. This is especially important where sulphate of lime may be formed. The presence of magnesia is objectionable on the ground of its forming magnesium salts, which, being hydroscopic, tend to keep the walls damp. If limestone is used in the place of sand, it should be of an hydraulic nature. The sand should be clean; *i. e.*, free from clayey matter. In some gas-works the manufacture is carried on entirely by hand-labor, iron forms being used to shape the blocks. One man using these molds, can make in an eight-hour shift from 400 to 500 blocks. In from three to four weeks the blocks are sufficiently set for use.—*Dr. Karl Bunte, Journal für Gasbeleuchtung*, Oct. 18, 1919. Abstracted through *The Technical Review*.

FIG. 4. DIRECT READING GRAVITOMETER



U. S. S. HENDERSON IN COMMISSION. THE PATCH IS OVER TWICE THE SIZE OF THE STABILIZER

Non-Rolling Passenger Liners*

Observations on a Large Stabilized Ship in Service

By Edward A. Sperry

NOW that it has been adequately demonstrated in the case of a number of important installations that a ship can be guaranteed against all rolling, a great forward step is possible and a new era opened up for the American passenger-carrying service. The traveling American demands the greatest possible degree of comfort, and shipping interests will not be slow to meet this demand by the latest and most up-to-date equipment cast strictly on American lines.

We will have at no distant date the Service-de-Luxe on the Atlantic and probably also on the Pacific, or, in American travel lore, the "Pullman Service of the Sea." Plans are already in progress for an extensive adoption of the new principle, so that the benefits and economies resulting from a ship guaranteed against roll will be available to the traveling public. This great forward step has been made possible by work going on here in America for the past fifteen years.

The point of large-scale demonstration has now been reached and full stabilizing moments, requisite for preventing all roll of even the largest ships, have been practically developed. The great principle thus finally established is that full stabilizing moments, can now be simply and effectively delivered to a ship that is quiescent and entirely free from motion. The motion of the ship itself having heretofore invariably been relied upon to create the quenching moments, anything like full extinction of roll has of course been impossible.

In all previous attempts to prevent rolling, the equipment has operated on the passive principle, depending on a certain amount of roll for the stabilizing moments, as stated; and the amount by which the roll has been reduced has never been satisfactory, nor have the means themselves been practicable. Another difficulty is that the phase lag is found to be insurmountable, the stabilizing effect—such as it is—arriving "the day after the fair."

The active gyro stabilizer solves the problem and works entirely independently of the motion of the ship. Delivering full counter-movements to a motionless ship, it is thus free to deal directly with the wave slopes themselves, *i. e.*, with the rolling increments of the sea as they are in the process of developing, even before incipient rolling has set in. The active stabilizer thus acts as a simple preventive of rolling, working in harmony with the slow period of the ship, yet dealing alertly with each increment as it arrives, irrespective of magnitude or direction; holding the ship most satisfactorily upon an even keel, apparently without effort; demonstrating how little is required to keep a ship from rolling, or, rather, from beginning to roll, if a basically preventive method is employed.

With the complete solution thus in hand, accomplished with a small and simple equipment, it is believed that the older passive types, with their great weight, fractional results, and uncertain operation, will become obsolete.

The equipment that brings about this important result is so simple and unique that a brief résumé of its development, the principles involved, and the performance of the non-rolling ship itself cannot fail to be of interest at this time.

The possibility of producing the non-rolling ship was known to the leading naval architects and investigators in England, notably the elder Froude, prior to 1880. A little later Sir Phillip Watts, one of the great masters of this noble art, became convinced from Froude's work that, inasmuch as it takes so little to hold a ship on an even keel and to prevent it from rolling, this very desirable result should be accomplished. As Chief of Construction of the British Admiralty, he, with a corps of engineers, at once started in to establish this great principle and to put it into execution, by building "anti-rolling tanks," as they were called, into the ship's structure and then filling these elongated tanks up to a certain critical point with sea water. These were expected to take on periodic oscillations from the ship's rolling motion, thus creating moments which would always be in opposition to the rolling and tend to reduce it. These tanks were actually built into two war vessels by the Admiralty, and experiments were undertaken with rather discouraging results, on two counts:

First, it was found that there were required a large tank and a large amount of water, representing quit an appreciable percentage of the total displacement of the ship—such a large

*Paper read before the Soc. of Naval Architects and Marine Engineers and published in the *International Marine Engineering*.

percentage, in fact, as to be prohibitive. The other point was the difficulty in maintaining proper phase relation between the natural period of the ship, the period of the water in the tank, and the period of the waves of the sea. More about this farther on. It will suffice to say that when this phase relation is not maintained, these tanks can easily become dangerous, tending to increase the roll rather than to reduce it.

Later the great English engineer, Sir John Thornycroft, undertook to accomplish the same result by a large horizontal pendulum operated hydraulically down in the hold of the ship; and the report of Sir William White—one of the Admiralty's greatest naval architects—on the actual operation of this device in a ship at sea in a storm (while Sir John and Sir William were dining together) makes one of the notable chapters in the early history of attempts at stabilization of ships. This stabilizer worked well at times, but it was found to have the same difficulty as the anti-rolling tanks, namely, in order to secure a sufficient reduction in roll to make the equipment commercial and practical, the weight of the equipment was prohibitive.

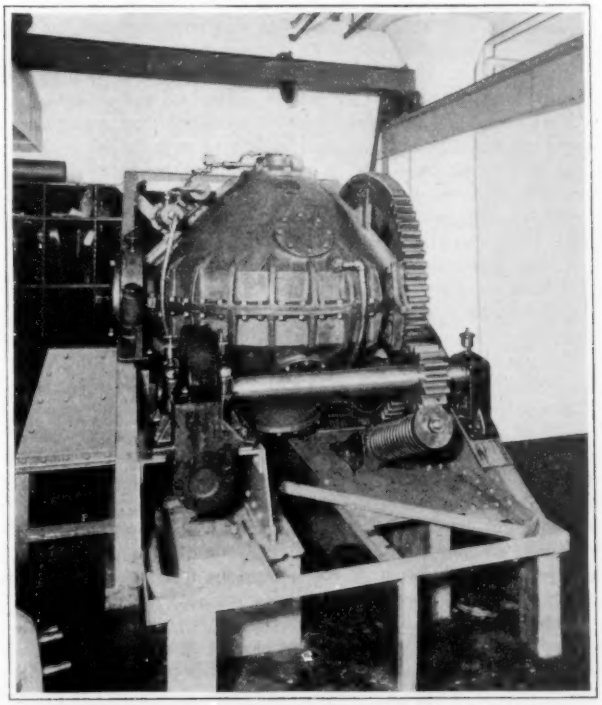
Later, Herr Frahm of Hamburg re-invented Sir Phillips' tanks, but though he made a contribution to the mathematical treatment of the subject and introduced some refinements in manual control valves and also in shape and contour, the tanks were found to be open to the same objections as those of Sir Phillip's.

Dr. Schlick, who had done such wonderful work in balancing marine engines, then came forward with his passive "gyrostat" or "Kreisel," as he called it. This was installed on a small torpedo boat and tested in the North sea. The Admiralty sent Sir William White, who, by the way, was a friend and admirer of Dr. Schlick, to report upon this device, and Dr. Schlick's rights were taken over by a leading English firm. The report is interesting. Sir William found this to be another device which depended for its action on the iniital roll of the ship—that is, the quenching moments were dependent solely upon the ship's motion—and these would have been quite effective as a roll reducer had it not been for the same unavoidable lag in phase, which seriously impaired their efficiency. In any event, the combined difficulties, some of which are cited, were sufficient to prevent the adoption of this device, or, for large ships, even its serious consideration.

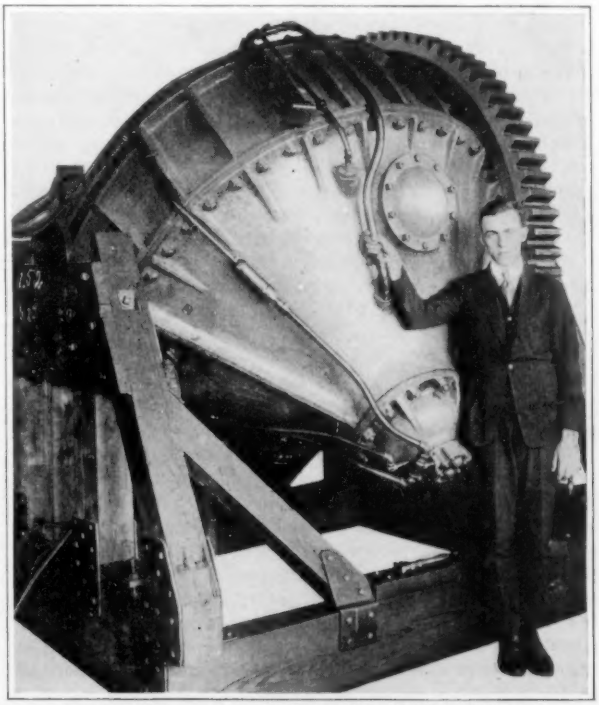
Later the action of anti-rolling tanks came under careful review by our own Taylor. This was before he became Admiral and Chief of the Bureau of Construction of our Navy, and while he still had charge of the big experimental tank at Washington, designed and constructed by him, and of the great collateral equipment that forms a part of the experimental and model department of the Navy. In this connection, Admiral Taylor, with his wonderful grasp of all this intricate phenomena, designed tanks that were unique; and to make his research and investigations complete he went at the matter in the most thorough manner, not confining his observations to one tank alone, but going to sea with a ship equipped with no less than three tanks. This was the most complete equipment, and the investigation was one of the most searching into the action of anti-rolling tanks that have ever been made the world over—as is characteristic of all of Admiral Taylor's work, which is conceived from a most complete and comprehensive standpoint and carried out in the most rigid and searching manner.

It is difficult to believe that the great art of naval architecture appreciates to the full the debt that it owes Admiral Taylor. Some little glimpse is had of the relation that this distinguished authority bears to the world-wide art, when we remember that at the time the "Hawk," warship of the British Admiralty, hit the "Olympic" near Southampton, within four hours of this memorable collision both sides had tried to reach Admiral Taylor by cable to retain him in the suit that they knew was imminent as the result of this accident. So the Government released Admiral Taylor to the Admiralty in order that important precedents might be established in the maritime world.

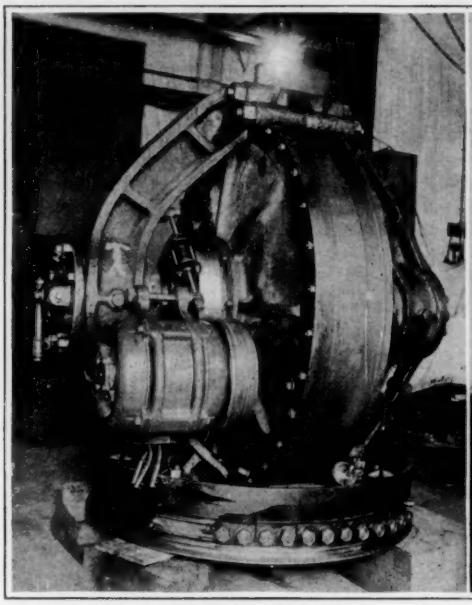
But to revert to Admiral Taylor's anti-rolling tank experiments. In this connection he reached certain conclusions, as he always does. These conclusions are interesting, as here we have the real crux of this whole matter. His verdict was that outside of the prohibitively large weights and extremely important athwartships space occupied by the tanks, neither the United States Navy, nor in fact any navy or marine, possessed the personnel requisite to keep the period in phase re-



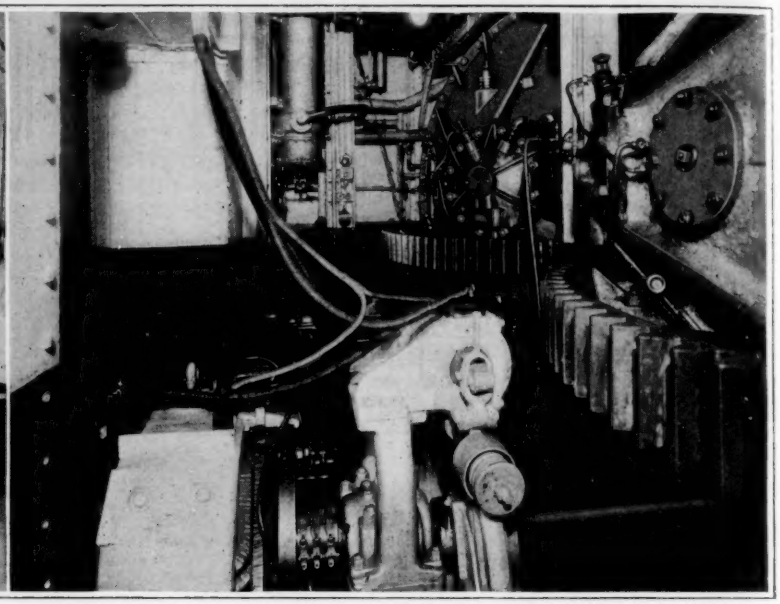
COMPLETE STABILIZER PLANT FOR 530-TON YACHT ASSEMBLED IN SHOP FOR TEST



STABILIZER FOR A LIGHT CRUISER MOUNTED IN SHIPPING FRAME



ORIGINAL ACTIVE STABILIZER INSTALLED ON THE DESTROYER WORDEN



STABILIZER ROOM ON U. S. S. HENDERSON. MAIN GYRO ON RIGHT, PRECESSION MOTOR IN FOREGROUND

lation with the natural period of the ship and also with the period of the sea. So at last this phase of the art has had the extremely great advantage of passing under critical review by probably the greatest living authority on these matters.

The difficulty with all of these attempts on this most important problem can be reduced to an extremely simple proposition: With all of these methods of attack, a pound weighs only a pound and its effectiveness is measurable in simple terms of the lever-arm of its application, or the distance from the center of oscillation of the ship at which the moments become effective. This is the reason for the excessive and even prohibitive weights necessarily present in all these methods of reducing the roll of ships.

Now what is wanted is not the reduction of roll, but the actual prevention of all rolling of ships, and it is just here that the powers and resources of the active gyroscope step in. For years engineers have observed the strange peregrinations of the gyroscope, but have failed to perceive the enormous powers that lie dormant in this simple apparatus, only awaiting the application of artificial "precession" to place it under perfect control and to render it abundantly serviceable for stabilizing even the largest ship. By the way, the larger the ship is, the easier it is to stabilize her.

In the gyro we have a most unusual illustration of the phenomena that Cicero classed among "real blessings"; that is, when nature's laws work to aid rather than to obstruct progress, by no means a too frequent occurrence in engineering. The gyro outclasses all other mechanisms in that, while its weight and cost vary as the cube of a lineal dimension, its stabilizing power varies no less than as the fifth power. This runs into a very great gain in gyro stabilizers for large ships.

Why is the gyroscope more available for solving this great problem than the tanks on the one hand or the great pendulum of Thornycroft on the other? The answer is simple. Whereas in the prior art, as we have stated, a pound is only a pound, in the gyroscope a new and extremely far-reaching situation is created. In arriving at the powers available to stabilize the ship with the gyro, every pound is multiplied by the velocity of the particle, so that a comparatively few pounds are actually capable of doing the work of tons. With the active gyro this is all held in phase, and, as described, is available for the important purpose of holding the ship free from even the beginnings of roll.

Those unfamiliar with the subject, and even some naval architects, have feared that the forces and stresses involved might endanger the ship's structure in case of a heavy storm. The exact nature and magnitude of these stresses are perfectly well understood and have now been brought under careful observation in quite a large number of equipments in actual service. We are therefore speaking from a wide range of accurate knowledge on this important item, and it will be interesting to know that the conclusions by the highest authorities are that a ship which freely rides the waves with its mast held vertical, being completely stabilized by the little gyro equipment in her hold, is subjected to less than one-fourth and often less than one-sixth of the very large strains present when it is allowed to roll under exactly the same storm and weather conditions and with the heading unchanged in the same sea. With the gyroscopic stabilizer equipment on board, we have the unique situation of being able instantly to throw it on or off, in action or out, at will, by stopping its slow precessional movements, so that we can observe exactly what happens under the two conditions and repeat each condition as often as we choose and hold each under complete observation as long as we choose, under any given sea or weather condition. And just such tests as these have been repeatedly made and studies pursued until they are well known and understood. Thus the presence of the stabilizer on the ship reduces and holds to a very low value the stresses and strains which in the case of an unstabilized ship in storms often rise to high and dangerous magnitudes.

Here again Admiral Taylor's work comes to the fore. The development of the active gyro stabilizer was aided materially through the encouragement given by this naval officer. He was among the first to appreciate the important results likely to follow the application of the active principle, *i. e.*, the ability to develop pure torque stresses in ships without change in loading or moving of weights or masses, and to direct these stresses and emplace them at will upon a ship independent of the state of motion of the ship itself and also independent of any particular position of the equipment upon or within the ship. This whole art certainly owes much to Admiral Taylor.

Everyone is familiar with the groanings, creakings, and weird noises that are always present in heavily laboring or rolling ships. These illustrate the stresses and strains to which she is being subjected. Imagine the sensation when the stabilizer is thrown into action and these sounds cease

forthwith, positively demonstrating that the heavy stresses have vanished. The stabilizer thus becomes one of the greatest safety devices yet invented imparting absolute security to the great hull and structure of the ship and materially prolonging its life. All of this, of course, is wholly outside of the

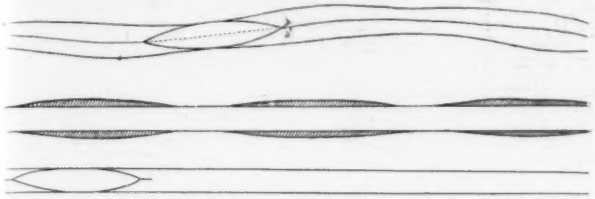


FIG. 1. LOSSES DUE TO HELM, ROLLING AND SINUOUS COURSE

The diagram at the top shows the path cut through water by stabilized vessel. The middle diagram shows that when the vessel is not stabilized it cuts a wider path as indicated above. The shaded area indicates proportional increase in power. The diagram at the bottom shows that further increase in power is required when the vessel yaws. The constant use of rudder absorbs power and tends to retard the vessel.

FIG. 2. CHARACTERISTIC STABILIZATION CURVE

consideration of comfort, which is one of the prime reasons for the installation on passenger ships.

In this connection it will be interesting from a technical standpoint to know that some time before the first stabilizer equipment was installed by the United States Navy, the great English naval architect, Sir William White, was brought to this country in consultation on this subject. He stated, after careful review of the facts, that from the naval architect's standpoint the strains introduced by the gyroscopic stabilizer in holding a vessel absolutely free from from roll were insignificant, and that if we laid hold of a single frame of an ordinary steel ship we would have a factor of safety of about six, and furthermore that these strains and stresses were only a small fraction of those existing in the hull and general structure of a ship when rolling in a storm.

This great authority went further and stated something that our highest authorities in this country then doubted, namely, that as soon as a ship was stabilized in a storm and rolling was prevented, that ship would not ship seas, but her decks would immediately begin to be dry and would remain dry. Although we did not at the time believe that this could possibly be true, our universal experience since we have had these installations in operation demonstrates the absolute truth of the statement, as the result of many observations and experiments, incidentally showing the great insight of Sir William.

Even some excellent authorities, before actually having the unique and extremely interesting experience of being aboard a stabilized ship, have confused a stabilized ship with a dock, expecting the waves to pound the ship when stabilized, and it is with great surprise and satisfaction that they have repeatedly discovered just the reverse to be true. A stabilized ship invariably rides the sea, gradually rising and falling with the sea with a wonderful degree of gentleness. Her masts quickly come to the vertical, and all pounding and splashing disappear as soon as stabilizing sets in.

Other facts have been learned from the performance of the stabilizer in heavy weather. It is found actually to contribute a number of definite economies in the operation of the ship. Anyone who has ever undertaken to pilot a heavily rolling ship and to hold her to her course has realized the enormous amount of "helm" that is constantly required, and the resulting very sinuous course that the ship takes in spite of the best efforts the helmsman can make under these conditions. The diagrams in Fig. 1 graphically illustrate this and other features.

No pains have been spared in studying this important phase of the contribution of the stabilizer. The gyro compass with its enormous directive power enables automatic records to be made of the most minute orientation of the ship. These have been secured and also simultaneous graphic records of the amount of helm being used by the ship, also automatic, so that there could be no question as to exactly what was happening. The study of these records has been full of interest, developing an accurate method of analyzing and aiding to establish the losses under this division.

Fig. 2 shows a characteristic stabilization curve and Figs. 3 and 4 are helm records.

Operating engineers and naval architects know that even

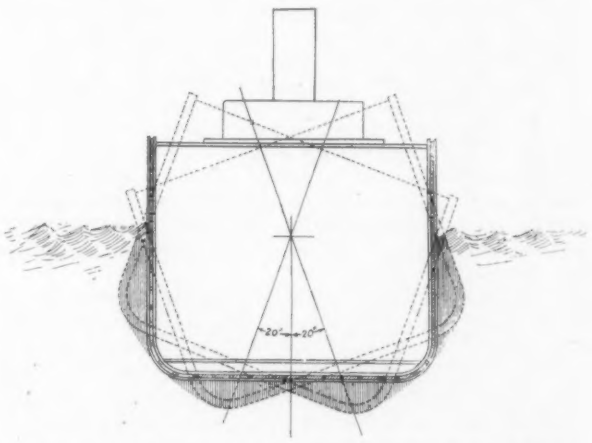


FIG. 5. RELATION OF POWER CONSUMPTION TO ROLL

The shaded area shows extra water disturbed. For a 37,000-ton vessel at 22 knots this means a loss of 3,100 horse-power.

a very slight amount of "helm" acts as a tremendous retarder in the forward progress of the ship, and especially is this emphasized when a very large amount of helm has to

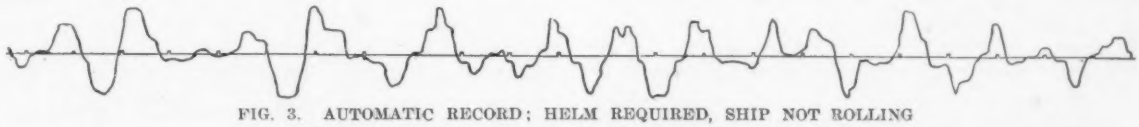


FIG. 3. AUTOMATIC RECORD; HELM REQUIRED, SHIP NOT ROLLING

Straight line indicates rudder center with one-minute intervals as jogs.

FIG. 4. AUTOMATIC RECORD; HELM REQUIRED, SHIP ROLLING HEAVILY

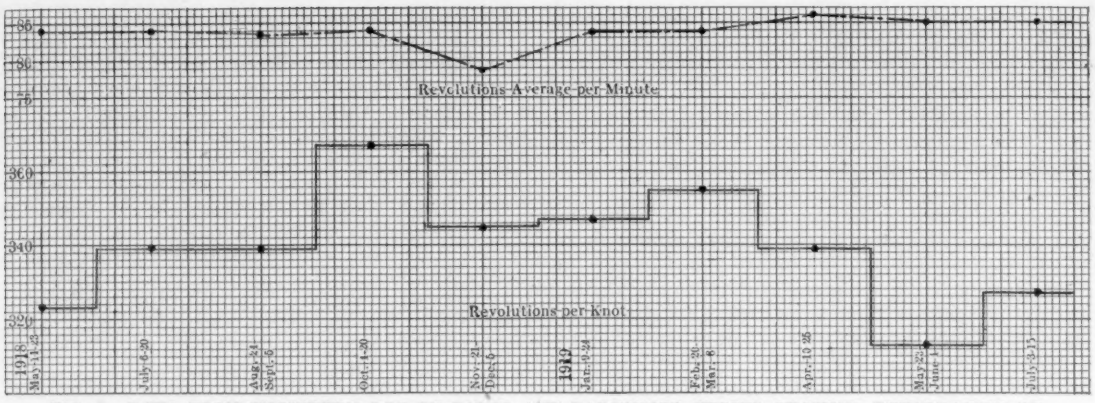


FIG. 6. DATA FROM ENGINEER'S LOG OF CARGO AND PASSENGER VESSEL SHOWING RETARDATION BY WEATHER CONDITIONS IN WINTER MONTHS

be constantly employed. This slows down the ship, uselessly wasting a great deal of the propulsive power of her engines. Again, the sinuous course that is invariably steered by a wallowing ship causes it to travel a considerable extra distance, always accompanied with a "bad angle of attack," causing a large extra power consumption. A stabilized ship is practically self-steering. This comes as a sort of a bi-product of stabilization, the stabilized ship requiring practically no helm, regardless of weather.

But there is a still greater source of power waste in rolling ships. As the hull constantly oscillates back and forth, its form-lines encounter and constantly displace laterally, with extra friction of impact, hundreds and even thousands of tons of water, and this persists, going forward with every roll. This, in connection with the extra wetted surface involved, added to the extra stream-line losses and skin friction impingement, especially when bilge keels are present, amounts to losses of very great magnitude in terms of actual horse-power wasted. Model experiments and resulting calculations indicate that these losses are much higher than have been supposed. Fig. 5 graphically expresses by the shaded area the tremendous increase in volume of water disturbed by a rolling vessel. For a 15,000-ton vessel at 18 knots—away inside the maximum roll—this loss may easily reach from 1,000 to 1,200 horse-power, and this power is absolutely dissipated and wasted.

Just here the stabilizer steps in with a saving of nearly all of this—practically the entire amount, minus the small and comparatively insignificant quantity of power that is required to keep the gyro wheel spinning in a vacuum. In the course of a very few voyages this power saving in terms of fuel saving amounts to enough to pay for the entire stabilizing equipment.

Very full corroboration of this is found in the service performance of a fast passenger and cargo ship, by taking ten consecutive trips over the same course in the same direction with almost identical load conditions and under conditions of constant propeller revolutions. These trips are sufficiently long, 4,600 miles, to be convincing in the results shown. This data has been plotted in revolutions per knot (see Fig. 6) and gives interesting and positive indication of the retardation of the ship owing to weather conditions. A very great amount of the losses in headway due to the retardation effect of the disturbances discussed above will be entirely eliminated by full stabilization. Let us examine what this means in dollars. Suppose the operating expense per 24 hours to be $6,000. The extra expense—that is, the expense over and above the average—in the stormy months amounts to not far from $100,000. This, taken with the amount saved through elimination of bilge keel losses, develops an earning capacity of the stabilizer of not far from 100 per cent per annum. All of this is over and above the many other important gains, both direct and indirect, resulting from the stabilizer installation.

The stabilizer achieves another economy of very great significance to both the operator and the passengers of fast ships. This is the practical avoidance of the necessity for slowing down ships in stormy weather or when heavy seas prevail, the ships being able to make practically the same time under storm conditions. This has been repeatedly demonstrated and is a result so startling that, when first experienced, it has often been claimed as an original discovery by the skippers of stabilized ships.

So insignificant are the stresses required to prevent all rolling that it is interesting to compare them with, or to state them in terms of the specific loading permitted by the underwriters. Take a concrete case of the transport Henderson, of 10,000 tons displacement, 488 feet length, with maximum beam of 48 feet and draught of 19 feet 9 inches—the allowable load per running foot for the section where the stabilizer is located is 14.5 tons. The load due to the weight of the stabilizer plus the maximum gyroscopic stabilizing moments, figured as load upon the vessel, is at maximum only 10 tons, and with average stabilizing moments about 6 tons per running foot. In other words, the stabilizer loads are much less than normal cargo loads. Some of the vessels carrying heavy machinery to France were loaded as high as 28 tons per running foot.

Another definite advantage secured by the stabilizer is the elimination of the bilge keels. Dealing only as they do with "V" square, they can never be of service other than in the heaviest rolling—at all other times they are a positive menace. The well-known drag of bilge keels in perfectly calm weather is not only ever present but represents positive losses, even in excess of those calculated. This has now been positively observed in the case of a large 20-knot ship, the performance with and without bilge keels for the same shaft revolutions, loading and trim being known. Moreover, a ship is never trimmed very accurately longitudinally, giving the bilge keels

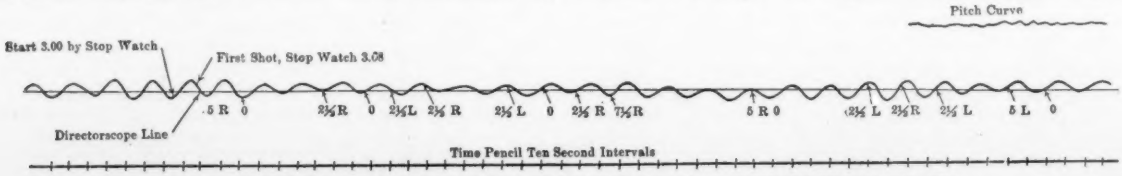

Pitch Curve
Start 3.00 by Stop Watch
First Shot, Stop Watch 3.08
Directorscope Line
5 R 0 2½ R 0 2½ L 2½ R 2½ L 0 2½ R 7½ R 5 R 0 2½ L 2½ R 2½ L 5 L 0
Time Pencil Ten Second Intervals

FIG. 7. AUTOMATIC CONSTANT ROLL IMPARTED TO U. S. S. HENDERSON AT SEA

a frontal attack component with the attendant eddies, consuming additional power of no small magnitude.

In rough weather the bilge keels afford an extra opportunity for the waves to lay hold of the vessel in rolling. Recently it has been definitely determined that the power required by bilge keels under the condition of pitching, even in a moderate sea, increases the propelling power to a point much beyond what had been supposed. In the case of a 10,000-ton vessel with standard keels, even with moderate pitching, an increased propelling power of about 9 per cent has been observed. In a stabilized ship it is possible to eliminate bilge keels. There should be no hesitancy in omitting keels, as an exceptionally large and successful fast passenger ship has been operated without bilge keels for years.

A reduction in stresses of the propelling machinery of a stabilized ship represents another important gain, especially in the case of twin-screw vessels where the windward propeller is held very much more satisfactorily to its duty—not only saving power but preventing the racking strains due to overspeeding when the screws are "rolled out." The efficiency of a propeller falls off abruptly as its blades even approach the surface, especially where the dip of the waves allows the slightest aëration of the water. For efficiency a propeller requires to be kept down in stiff water.

Prevention of deterioration in cargo applies especially to ships carrying live stock. Figures have been furnished by a concern transporting horses during the war showing that, in a heavy storm during a single trip, their losses per trip often amounted to $30,000 or $40,000, a sum sufficient in a short period to equip the vessel with a stabilizer.

The ability to roll the ship has proved in actual experience to be important in case of emergency to free the vessel from sand and mud banks, by opening the contracting crevices and gradually liquifying the encumbent mass. This has been discussed in a former paper, also the field of the active gyro in rolling ice-breakers and preventing them from freezing in when cutting through rivers and harbors during the winter months. The most important use for rolling however is as an aid to gunnery.

As outlined, we have been accumulating a large amount of actual sea experience with various sized equipments. The Government has been of the greatest assistance in encouraging the development. The war has seriously interfered with the work, but even during this period the Navy has allowed us to complete the largest gyro equipment yet attempted, and though the installation has been retarded by the ship's being in constant transport service, this fact has offered additional opportunity for final testing. One of the engravings shows a corner of the gyro room on the Henderson with the precession motor in the foreground, and another illustration shows the little control room with the rotary for generating A. C. current for spinning the gyros in the background. Directly in front of the rotary converter is the vertical gudgeon bearing which transmits the stabilizing moments through the ordinary steel decking to the ship's structure. This ordinary steel decking is found to carry the stabilizing moments with a large factor of safety. In the foreground is the special control gyro for the ordnance tests. In this case the gyro may operate in a single period successively as a stabilizer or as rolling equipment. Fig. 7 shows a curve of the Henderson automatically rolled by her special equipment when under full headway.

This ship has operated with as high as 11,500 tons' displacement, and the stabilizer has been repeatedly operated under overload conditions without difficulty, the journals running with perfect temperature control under the heaviest duty, including overload conditions. Even different lubricants have been tried, all giving about the same results; in fact, the plant, since the journals have been worked in, has operated normally in service, and the records show that the guaranteed stabilizing moments have been easily developed.

This equipment has undergone additional protracted tests as an ordnance fitting, reaching results in this connection which are very interesting. The exacting nature of these tests and their severity have contributed in no small measure to another extremely interesting result as follows: The complete knowledge we now have of the behavior of these equipments and the measured results and records have placed us in a position to guarantee unqualifiedly the stabilization of practically any ship to accurate specification and also the equipment by means of which this important result is secured.

The Trans-Sahara Railroad

Technical Features of Its Construction

MUCH interest is being felt by France in the projected railroad lines across the desert of Sahara, between south Algeria and the French territory in western Africa. On the 27th of September, 1919, *Le Génie Civil* (Paris), published maps of Africa indicating the railroads already constructed and the trans-African lines which had been proposed before the war. We reproduce these maps with a summary of the accompanying article.

Le Génie Civil has already published an account of the two principal trans-Saharan railroad lines—first that of the Chief Engineer of Roads and Bridges, Souleyre, who projected a line starting from Biskra and running through Touggourt and In-Selah, towards Timbuctoo, with a branch line connecting with Lake Tchad; and secondly the plan proposed by M. André Berthelot, a brief resumé of which appeared in *Le Génie Civil* for July 25, 1914, whose point of departure was Colomb-Béchar, the terminus being South-Oranais (Fig. 1).

Still other promoters projected a more extended program of communication between Algiers, the Niger, the Belgian Congo and British East Africa, by branch lines running respectively through the region of Timbuctoo, the terminus (Kano) of the Nigerian railroad, then Stanleyville, along the Congo River, and finally, Port Florence on Lake Victoria (the terminus of the British line, whose other end is at Mombassa, a port on the Indian Ocean).

Thus it was proposed to connect Algeria (and consequently Morocco and Tunisia) first with western and equatorial Africa whose valuable products (particularly the mineral wealth of Katanga in the Belgian Congo) hold out flattering prospects; and finally, by an agreement with the future Cape to Cairo line, with the vast and prosperous regions of South Africa.

Still other projects, scarcely less impressive, have been a matter of recent agitation: the Paris-Madrid-Tangier-Dakar line, to which we shall refer further on, and that of the Trans-Soudan line started from Dakar (and from Conakry) and running towards Fort-Lamy and Khartoum, with its terminus at Port Soudan and Djibouti on the Red Sea, recommended by M. Tilho.

The new economic conditions caused by the war do not permit the realization, at any rate in the near future, of projects having so large a scope; when even the reconstruction of a few hundred kilometers of the lines destroyed in the north and the east of France is, at present, a difficult task, and the service of our main lines is so uncertain that the Paris-Lyons express is commonly many hours late, etc., etc., it is easy to see that the French government cannot undertake such an onerous enterprise.

Nevertheless, the future of our immense African possessions must be kept in mind, and it is permissible to indicate a few land-marks which may facilitate the labors of the next gen-

FIG. 1. MAP OF AFRICA SHOWING EXISTING RAILROAD LINES AND LINES PROJECTED

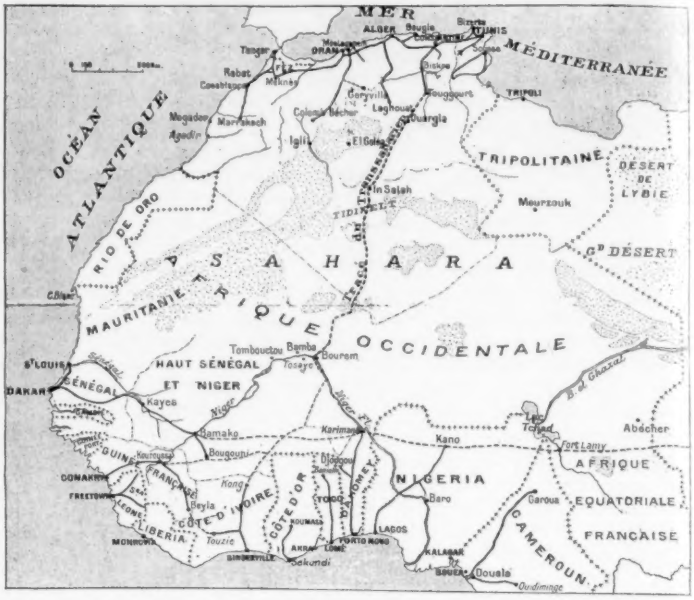


FIG. 2. MAP OF WEST AFRICA SHOWING THE COURSE OF THE TRANS-SAHARAN LINE PROPOSED BY M. GODEFROY

eration. It is this sort of thing which lends interest to two memoirs recently published by Lieut. Colonel Godefroy, the director of the Biskra-Touggourt line and by M. L. Durandeau, director of the Bureau of Technical works in the territory of South Algeria. After passing in review the economic conditions and the present state of affairs in our African colonies . . . Lieut.-Colonel Godefroy tackles the question of the trans-Sahara, properly so designated. . . . He justly considers that the ambitious Trans-African projects contemplating a continental and trans-continental traffic connecting London and Paris with Central Africa, on the one hand, by way of Marseilles, Algiers, the Belgian Congo, and the Great Lakes, and with South America on the other, by way of Marselles, Algiers, the loop of the Niger and the transit from Dakar to Pernambuco, are not at present feasible. . . .

The same conclusion was reached by M. Suss, who read an article before the Society of Civil Engineers on July 15th of last year, concerning the project of a connection between Paris-Tangier-Dakar by a new line of standard gage, traversing the whole of Spain from Irun to Algeciras by way of Madrid, passing under the Straits of Gibraltar through a 40-kilometer tunnel, or more simply perhaps by means of ferry-boats similar to those which are operated successfully both in Scandinavian countries and between France and England, and running directly from Tangier to Dakar by way of Fez (3,500 kilometers), thus securing a fast service from Europe to South America by way of Dakar. M. Godefroy considers that if it is desired to create a connection between Algeria and the Cape to Cairo line, it will be more advisable, instead of seeking to form a junction with this line in the middle of Africa, to connect with it at Cairo by a line running through Fez-Algiers-Tunis-Tripoli and the littoral of the Tripolitan and Cyrenaïc territory. Besides this general traffic such a line would have the advantage of serving as a means of transport for the great numbers of Moslems who annually make a pilgrimage to Mecca, and whose numbers fill entire ships, and for whose convenience the Turkish government built the line from Damascus to Medina in 1908.

A portion of the Fez-Cairo line is already in existence as far as Gabès on the one side and from Daba to Cairo by way of Alexandria on the other side; furthermore, the strategic line built by the British to supply their expeditionary force in Palestine could be easily prolonged to the Mecca line.

M. Godefroy is more interested, however, in the idea of an actual Trans-Sahara line having for its object the connection of South Algeria with the loop of the Niger at Tosaye, a point in the vicinity of Bamba and of Bourem (Fig. 2) where it is expected that a junction will be made with the future railroads of French West Africa.

The projected line whose construction he advises starts from Touggourt, the present terminus of the Algerian system (the Algiers-Constantine-Biskra-Touggourt lines); it descends by way of Ouargla (the date-bearing region), and In-Salah, traverses the Tidikelt and the Adrar, terminating at Bourem, or about 2,360 km. in round numbers. At the chosen junction at Tosaye the Niger is confined between two steep banks where the construction of a bridge would present the minimum of difficulty. By adding to this length that of the Algiers-Touggourt line (640 km.) the complete trajectory from Algiers to the Niger would represent 3,000 km.

It may be added that at the present time the line proposed is outlined as far as In-Salah by the automobile tracks recently built beyond Touggourt.

ELEMENTS OF THE TRAFFIC.

Travelers.—French West Africa might furnish numerous passengers in Algeria and in Tunisia to supply the shortage of labor in the mines and in agriculture; this source might yield a considerable and almost constant current of natives between the north and the south. Passengers of a better class would evidently be but few in numbers, the majority being officials provided with free transports of travelling at reduced rates. On the other hand the Sahara line would readily take the place of maritime passage for mail and parcel post.

Various Products.—The traffic in merchandise would consist mainly in rice from the Soudan, cattle on foot or refrigerated meat from the loop of the Niger bound north and southbound, of wheat, fruit, Algerian dates, fabrics and manufactured products, as well as tools, etc., from Europe. . . .

Technical Conditions of Construction.—The two brochures cited above are particularly interesting in their presentation of the technical conditions involved. . . . We give by preference a resumé of M. Durandeau's remarks, since while agreeing with those of Godefroy they enter more into detail. . . .

Width of Gage.—The standard gage has been recommended by Souleyre and Berthelot; it exists on only a part of the Algerian system, but the South Oranais lines have a gage of 1.05 m., those of South Algeria a gage of 1 m.: Since a

transfer of freight is required already, for this reason, it would appear to be natural to continue with one of these widths, the Sahara line being the immediate prolongation of one or the other of these systems, according to whether the line started from Touggourt or eventually from Colomb-Bechar. Economical reasons practically impose this solution, which furthermore presents no grave inconveniences. It is quite erroneous to connect the idea of a narrow gage road too readily with that of a light traffic road . . . certain narrow gage roads, in fact, carry very heavy traffic: for example, the mining road of the Zaccar, having a gage of 0.75 m., which annually carries to the Miliana station on the Algerian P. L. M. more than 100,000 tons of minerals; moreover, in former German East Africa the Otavi line, which has a gage of only 0.60 m., but is 671 km. long, carried 107,000 tons in 1913. Furthermore, a narrow gage line, having curves with a minimum radius of 500 m. and grades of a maximum of 10 per cent lends itself with perfect ease to high rates of speed, provided the track is strong, has cross-ties sufficiently close together, and particularly is provided with heavy rails of sufficient length.

Furthermore, if the amount of traffic proves large enough in the course of a few years to justify a change of the narrow gage into a gage having a width of 1.44 m., such a change could readily be made without interrupting the service by first making a gradual preparation for the increasing width of the road-bed and the bridges, and then by inserting between the present cross-ties those of a standard length to which the new rails are attached. In this manner the change from the narrow gage could be made at leisure. The apparatus required, which are, on the whole, few in number, could be prepared in advance, placed alongside the laying point, and put in place at the time the service was changed.

M. Durandeau proposes the laying of a track with double-headed rails in 20 m. sections, weighing 35 km. per meter, resting upon rail-chairs and upon cedar ties measuring 2.20 m. by 0.24 m. by 0.14 m., or else upon metal ties 45 km. each in weight and 1.90 m. in length. Such a track would be able to support loads of 17 tons per axle-kilometer at speeds of 60 km. per hour.

The choice of the double headed rails mounted upon rail-chairs is justified by the necessity for raising the track as high as possible above the ballast. This is desirable in the first place, in order to facilitate the passage of the fine sand driven by the wind between the ties from one side to the other of the line, thus diminishing the danger of having the rails covered with sand, and consequently to protect the rails as much as possible from the dangerous corrosion due to the saline character of the ground throughout a large part of the territory to be traversed; this ground contains chlorides and sulfates which, under the influence of the very considerable variation in the humidity of the ground, set free acids which attack the rails and fish plates very rapidly. It is evident that metal ties are impossible in regions of this character.

In order to prevent the drifting of sand over the switches, a circumstance which has often caused accidents on the lines of South Algeria, it is a good plan not only to support the rails on rail chains but also to place the ties upon a bed composed of other ties running parallel to the track and joining together. If this be done the sand will run between the rails and the ties and will fall upon the aforesaid bed whence it is rapidly driven by the wind.

The question of the width of the road-bed is of primary importance for a track through the Sahara Desert. The road-bed lies most often upon sandy ground which is eroded by the wind; the slopes of embankments are diminished on the windward side so that little by little the road-bed decreases in width up to the ends of the ties, and in cuts the sand frequently drifts over the track.

Furthermore ballast made of broken stone of good quality is very expensive because of the enormous quantities required and the considerable distance over which it must be transported, while ballast made of crushed gypsum, which can be obtained upon the spot, quickly crumbles, thus injuring the road-bed, the rails and even the health of the crews.

It is advisable in laying out the track to avoid the immediate proximity of sand dunes so that it will be possible to employ some method of fixing those dunes which threaten to invade the track before they become dangerous. This stabilization may be accomplished by planting tamarinds or by driving piles in them.

The line along which the necessary stations are not very numerous should be laid out rather with a view to avoiding grades than with the idea of procuring an indefinite straight alinement. The reason for this is that by thus preserving curves of large radius, the visibility of the track and the maximum of the speed attainable can be maintained almost as well as a long straight line, and one will, furthermore, be able to save the extra energy required by up grades or wasted unnecessarily in braking the train on down grades.

Masonry.—The serious inconvenience referred to with respect to the possible corrosion of the rails also affects mortars made of lime or of cement to which the saline nature of the argillaceous territory of the great *chotts* (lakes which have become nearly dry) or of the territory containing gypsum, likewise very abundant, is distinctly injurious.

With respect to this the experiments in masonry work of the South Constantine lines are unhappily very convincing—the alternations of heat and of cold, of drought and of damp, exert a very unfavorable influence upon the resistance of elements, especially since they are themselves unstable as respects chemical composition and since they are often applied by careless and incompetent workmen.

M. Durandeau also advises against the use of hydraulic binding substances, making use preferably (as in the case of a bridge on the Biskra-Touggourt line) of hewn stone and of cedar, which is abundant in Algeria, and which is not subject to decay; in default of this he recommends masonry built of dry stones, and finally the employment of thick lime when mortar is indispensable.

In the Sahara, where there is a lack of building materials, one finds only rubble made of gypsum, which can be conveniently used for all masonry, together with a mortar made of thick lime and the sand of the locality; the Biskra- Touggourt line constructions are built in this manner and have proved satisfactory.

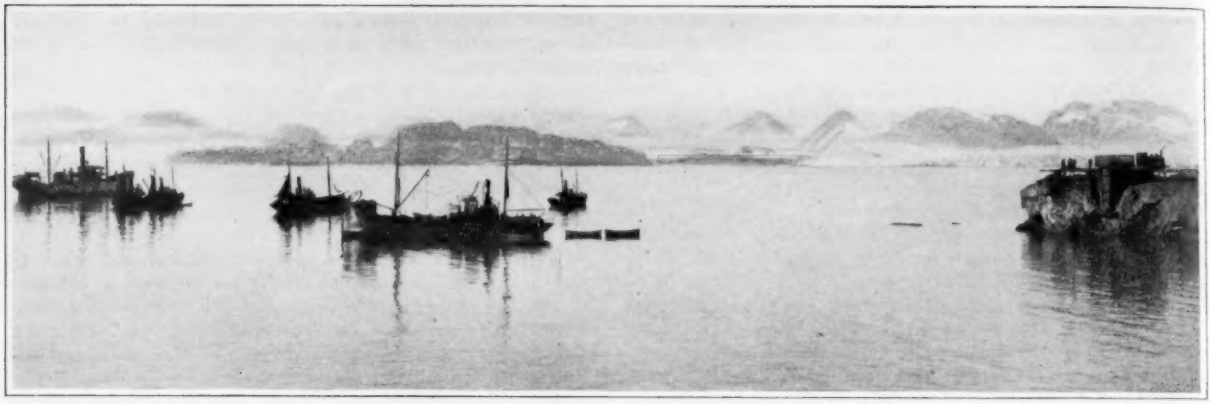
Mode of Traction.—The scarcity and poor quality of the water obtainable in the desert areas of the Sahara precludes the use of steam for motive power. During the work of construction there is no time to make the necessary search for subterranean waters without retarding the progress of the work; then, too, the expense of bringing fuel from Europe would be prohibitive. Even in ordinary established traffic it is difficult to employ steam engines.

It appears preferable to lay plans for using either motor tractors of the Diesel or Still type, or else electric traction by means of a current obtained from groups of motors of the same kind. This subject requires some study since all the required details are not yet understood. However, the rapid progress of mechanics and of electricity leads us confidently to expect that the problem will be solved in due time. . . .

THE SHRINKAGE OF VENEER.

ACCORDING to present practice, logs which are to be cut into veneer are either steamed or soaked in hot or boiling water for several hours to soften the wood. The claim is sometimes made that the veneer from boiled logs is likely to shrink and swell less with changing moisture content than the veneer from steamed logs. This point was made the subject of investigation by the Forest Products Laboratory.

Although these tests were crude, they indicate that the shrinkage of veneer from boiled and steamed logs is practically the same.



KINGS BAY FROM COAL HARBOR, THE MINING SETTLEMENT OF THE NORWEGIAN KINGS BAY COAL COMPANY ON ITS SOUTHERN SHORE

On the right is shown the terminus of the most northerly railroad in the world (78° 56′ N.) The line, 1½ miles long and of 36-inch gage, carries the coal from the mine to the harbor.

The Norwegians in Spitsbergen*

Their Rightful Claims to Sovereignty of This Archipelago

By Charles Rabot

Société de Géographie de Paris

Special interest attaches to this article in view of the fact that the Supreme Council of the Peace Conference at Paris on November 21 approved the text of an agreement granting political suzerainty over the Spitsbergen archipelago to Norway.—EDITOR.

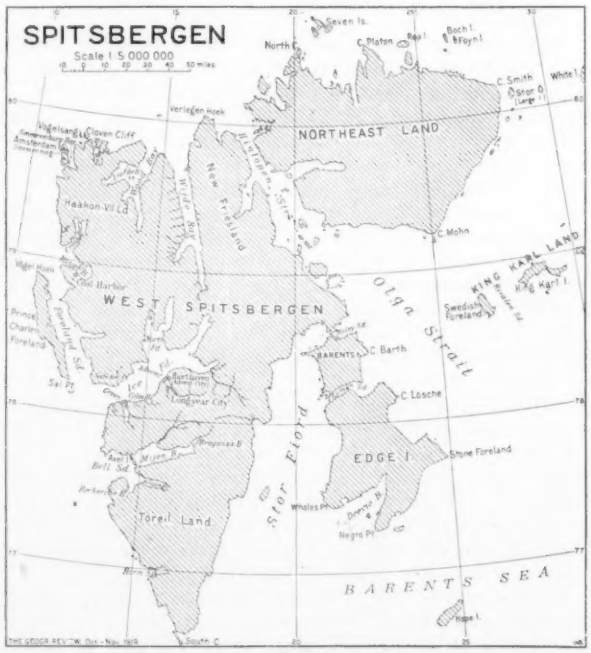
SEVERAL papers concerning Spitsbergen have recently been published, but they are incomplete and inaccurate, their authors being unaware of the great work done by the Norwegians in this archipelago and of the recent historical research work of the Dutch. It may therefore be useful to attempt to present a comprehensive account of geographical progress in Spitsbergen and of the industrial development of this polar land as well as its political history.

ICE CONDITIONS ON SPITSBERGEN COASTS.

Owing to the climatic effects of a branch of the Gulf Stream, the western coast of Spitsbergen and the westernmost part of its northern coast are usually ice-free from July to October. Sometimes the western coast is open until December. In 1892, on July 29, 30, and 31, between Jan Mayen and Ice Fiord, I did not see a single cake of ice. Thanks to these circumstances tourist-crowded liners in service before the war used to push up from the northwestern corner of Spitsbergen as far as the eightieth parallel to let their passengers enjoy a view of the polar pack. In no other part of the world can one reach so high a latitude in open water.

By contrast, a polar current flowing past eastern Spitsbergen, carrying a large amount of ice, blocks the eastern coast of Northeast Land, Barents Island, and Edge Island. Off the southern coast of the last-named island a branch of this current takes a westerly direction, rounds South Cape, and runs northward between the Gulf Stream and the western coast of Spitsbergen, carrying masses of ice which generally disappear by early summer. Such is the normal state of the ice, but it may be interfered with by the winds. In spring and summer northern and eastern winds prevail, the polar pack drifts southward and closes the generally open waters off the northern coast, while the eastern ice drifts southward also, opening Stor Fiord and the sea off the eastern coasts of Northeast Land, Barents Island, and Edge Island. A great deal of this ice skirts South Cape and arrives on the western coast at the southern point of Prince Charles Foreland. In 1915 so much eastern ice gathered on the western coast that Bell Sound and Ice Fiord were blocked and navigation was very difficult until the end of August. Probably not since the discovery of Spitsbergen, certainly not in the last fifty years, had the western coast been so obstructed by ice.

It also happens, but very rarely, that owing perhaps to the greater flow of the Gulf Stream, the sea all about Spitsbergen remains open the greater part of the summer, and in such seasons the circumnavigation of the archipelago becomes possible. This was the case in 1918 and, before that, in 1886, 1887, 1898, and 1899.



SKETCH MAP OF SPITSBERGEN

*Reprinted from the *Geographical Review* for October-November, 1919, published by the American Geographical Society, Broadway at 156th Street, New York. Photographs loaned by the *Geographical Review*.

PANORAMA FROM BEN NEVIS, A SUMMIT 913 METERS HIGH SOUTHEAST OF RED BAY, NORTHERN WEST SPITSBERGEN
The view, which extends from south to northwest, shows practically the whole extent of the Grand Glacier, which ends in Red Bay on the right. (Photo by Captain Gunnar Isachsen.)

HISTORY OF EXPLORATION.

The story of the geographical exploration of Spitsbergen can be divided into three periods: (1) the Dutch-English, which lasted until the beginning of the eighteenth century; (2) the Norwegian-Swedish, between the end of the eighteenth century and the opening of the twentieth century; (3) the Norwegian, since 1906.

DUTCH-ENGLISH PERIOD.

The old Icelandic annals regarding the discovery of Spitsbergen by Norwegians in the eleventh century are vague, and the journey of Willem Barents in 1596 is considered as the first authenticated voyage to this Arctic land. The celebrated Dutch seaman visited only the western coast and a part of the northern coast of the main island, and the discovery of the other islands has been credited to English "adventurers" of the Muscovy Company. But this claim must be revised. The globe of the Dutch cosmographer Plancius, engraved in 1612 and newly discovered by Dr. F. C. Wieder, delineates the northern coast beyond Hinlopen Strait, the Seven Islands, the western and southern coasts of Edge Island, and Hope Island. Thus, previous to the English, even "before 1614 the entire circumference of Spitsbergen was known to the Dutch, except the vicinity of Heley Sound (Helis Sound) and the east coast of North-East Land and Edge Island, so that the Dutch may rightly be called the discoverers of the entire Spitsbergen group."[1]

[1]The Dutch Discovery and Mapping of Spitsbergen (1596-1829). Edited by order of the Dutch Minister for Foreign Affairs by Dr. F. C. Wieder. Published by the Netherland Ministry for Foreign Affairs and the Royal Dutch Geographical Society, Amsterdam, 1919. This splendid volume contains the reproduction of 83 maps of Spitsbergen between 1596 and 1829.

About the middle of the seventeenth century, while the English whale fishery declined, the Dutch whaling industry had a rapid development, which was of great advantage to geography. Returning home, the Dutch whalers gave to the cosmographers of Amsterdam information concerning Spitsbergen, so that in Holland there was continuous and uninterrupted progress in the cartography of these polar islands. From 1594 to 1892, according to Dr. Wieder, more than two hundred maps of Spitsbergen were published in the Netherlands. To the Dutch we are indebted for the first cartographical documentation concerning these islands. During two and a half centuries the Dutch were the masters of the cartography of Spitsbergen.

NORWEGIAN-SWEDISH PERIOD.

Toward the end of the eighteenth century the Dutch whale fishery declined, and the Norwegians arrived at Spitsbergen in order to hunt the walrus, seal, polar bear, and reindeer in summer. Their activity was at that time limited to the western coast and to the easily accessible part of the northern coast. In 1827 B. M. Keilhau, professor at the University of Christiania, chartered one of these sealing vessels and paid a short visit to Bear Island and Spitsbergen. This was one of the first scientific expeditions to these islands and one of the most successful. The geological, paleontological, and botanical studies which Keilhau had the opportunity of making during his voyage are fundamental. In 1837 the Swedish professor S. L. Lovén also made a scientific trip to the western coast in a Norwegian vessel.

In 1858 the second chapter of the history of Spitsbergen opens with the geographical exploration of the archipelago both by Swedish scientific expeditions and by Norwegian walrus hunters. From 1858 to 1908 twenty Swedish expedi-

LOOKING SOUTH DOWN ERDMANN GLACIER (RIGHT AND CENTER FOREGROUND) AND ITS OUTLET VALLEY TO THE FURTHER SHORE OF BELL SOUND (IN THE BACKGROUND).
The massif on the right is Mt. Conway, that on the left, South Halland Ridge. (Photo by Engineer Koller.)

tions went to Spitsbergen under the leadership of scientists like Otto Torell, A. E. Nordenskiöld, A. G. Nathorst, Baron Gerard de Geer and others. Besides valuable scientific studies they published in 1865 the first chart of the archipelago based on surveys. This chart has been the basis for later ones representing fresh discoveries. The British Admiralty's chart, reproduces the results of the Swedish surveys.

DISCOVERIES BY NORWEGIAN WALRUS HUNTERS.

During the second half of the nineteenth century no Norwegian scientist took part in the exploration of Spitsbergen.

LONGYEAR CITY IN SUMMER

Nevertheless important discoveries were made by Norwegians. About the year 1850 game became scare in the easily accessible parts of Spitsbergen, and Norwegian walrus hunters sought new grounds in the generally ice-blocked waters stretching northward and eastward and made important discoveries in the hitherto unknown eastern parts of Spitsbergen.[2]

The first step in this direction was taken in 1847, when Captain Lund navigated Thymen Sound, between Edge Island and Barents Island, for the first time. At that time Barents Island was not known to be an island; it was represented as a large foreland of West Spitsbergen, and Heley Sound was shown as a fiord. In 1858 Captain Johan Nilsen crossed this inlet from sea to sea, demonstrating the supposed fiord to be a strait. By this discovery the features of eastern Spitsbergen were also completely changed. In 1859 another Norwegian seal hunter, the well-known Elling Carlsen, cruising eastward of Edge and Barents Islands, found himself near an unknown land. This was the islands now named King Karl Land but then identified with Giles Land, an island seen in 1707 by Commander Giles, the position of which remained uncertain at that date. Three years later, in 1861, Carlsen for the first time circumnavigated the whole archipelago—a splendid achievement. During this cruise the true nature of Northeast Land was ascertained. It was discovered that the eastern coast of this large island is entirely occupied by a great glacier discharging into the sea and forming the eastern outflow of an inland-ice mass which covers the whole island. In 1864, off the eastern coast of Northeast Land, another gallant Norwegian hunter, Tobiesen, rediscovered Stor Ö (Large Island), seen by Dutch whalers in the seventeenth century.

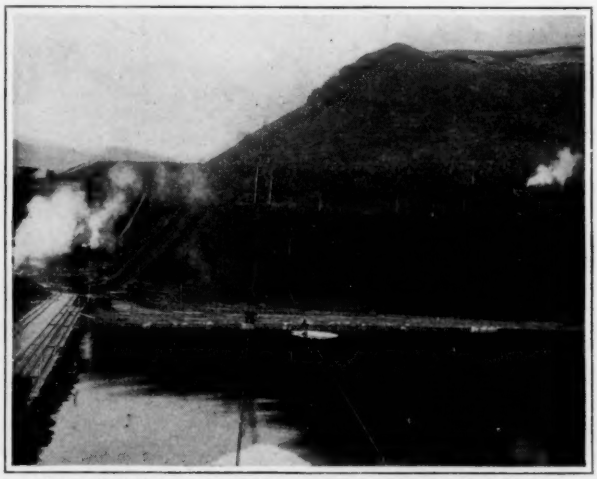
In 1867, Rönnback circumnavigated West Spitsbergen and discovered a group of small islands on the western coast of Hinlopen Strait in 79° N.

In 1871, an English sportsman, B. Leigh Smith, chartered a Norwegian schooner under the command of Captain Ulve, an expert Norwegian ice navigator. Reaching the southern and later the northern coast of Northeast Land, they stated that this land stretched about 43 nautical miles farther eastward than was formerly believed.

In the following year knowledge of eastern Spitsbergen was advanced by Norwegian seal hunters. Taking advantage of an open season, Altman, Johnsen, and Nielsen reached King Karl Land and reported that there were several large and small islands divided into two groups by a large sound. Johnsen landed on the northeastern point of the eastern group.

In 1876 and 1887, eastward of the northeastern point of Northeast Land, two Norwegian walrus hunters, Kjeldsen and E. H. Johannesen, came in sight of an unknown island, White Island, the true Giles Land. In 1889, another Norwegian walrus hunter, Hemming Andreassen, completed our knowledge concerning King Karl Land by navigating the northern part of the sound dividing the two main islands, Svenska Förland (Swedish Foreland) and King Karl Island. This sound was called Rivalen Sound from the name of Andreassen's ship. According to Professor Nathorst, the sketch map of this Norwegian walrus hunter was not superseded until the survey of this group of islands was made by the Swedish expedition of 1898; it is, however, much more accurate than the map that Dr. W. Kükenthal, the well-known zoölogist of Jena, published after visiting King Karl Land in a Norwegian hunting sloop that same summer. So strong is respect for established authority in old Europe that in a new issue of their maps of Spitsbergen the British and French hydrographic offices reproduced the incorrect sketch made by the German scientist rather than the accurate one by the Norwegian skipper.

Finally, in 1898, Norwegian hunters, starting from the northeastern corner of Northeast Land, discovered beyond



THE WHARF AND CABLEWAY ON ADVENT BAY FOR UNLOADING COAL FROM THE MINE AT LONGYEAR CITY

White Island a new island, which they named Victoria Island. These seamen also reported that Spitsbergen and Franz Josef Land have a fringe of islands between them. These two polar lands form a dam which prevents the polar pack from flowing southward in great masses. To this circumstance northern Europe is indebted, in part, for its relatively mild climate.

To summarize, we may say that in eastern Spitsbergen the Norwegian walrus hunters did admirable pioneer work, opening the way for further scientific expeditions. Also, geography is indebted to them for determining the directions of ice drift around Spitsbergen.

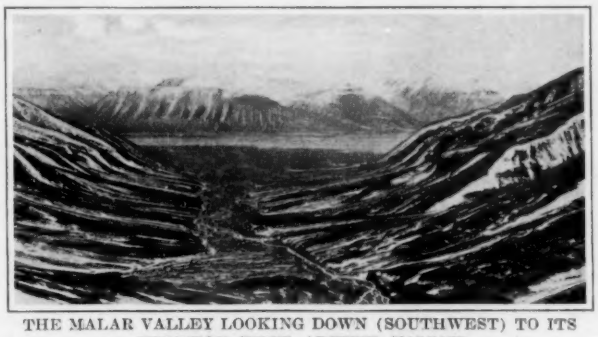
In order to complete the description of the contributions to our knowledge of Spitsbergen made by Norwegian hunters, it must be added that, of the trappers who have been winter-

[2]The survey of the Norwegian exploration of Spitsbergen here given summarizes a statement compiled by order of the Norwegian Government by Adolf Hoel, of the University of Christiania, the leading Norwegian explorer of these islands in recent years.

ing in the islands since the last years of the nineteenth century to catch bear and fox, eighteen parties made regular meteorological observations, both on the western and the eastern islands, with instruments lent by the Meteorological Institute of Christiania, and thus added substantially to our knowledge of the climatology of this Arctic land.

RECENT NORWEGIAN SCIENTIFIC EXPLORATION IN THE INTERIOR.

In 1906 the last chapter in the exploration of Spitsbergen was begun by Norwegian scientists, using new methods of exploration. Until then few expeditions had been undertaken in the interior, so that practically the whole inland portion of the islands remained a *terra incognita*. In 1906, the Prince of Monaco, having taken Spitsbergen waters as a field for oceanographical research, began the systematic survey of the western island. Establishing his headquarters in Cross Bay, he entrusted the mapping of the mountainous massifs stretching from that bay to Smeerenburg to Captain Gunnar Isachsen of the Norwegian army, who had been the topographer of Sverdrup's expedition to the American Arctic Archipelago. With a staff of Norwegian surveyors and naturalists and with Dr. Louet of the French army, Captain Isachsen admirably fulfilled his task in two summers.



THE MALAR VALLEY LOOKING DOWN (SOUTHWEST) TO ITS JUNCTION WITH ADVENT VALLEY
(Photo by Engineer Koller, 1917.)

The results are of great value.[3] About 200 square miles of Spitsbergen's ice world were mapped by accurate methods on the scale of 1:100,000 with contours of elevation. Never before had such a great area of the interior of Spitsbergen been surveyed, nor an Arctic land mapped so accurately. This successful expedition aroused in Norway a still greater interest in this region. The Norwegian parliament and private citizens granted large subsidies for pursuing the work initiated by Isachsen. Henceforward the foundations were laid for a systematic survey of the westen fiord region of West Spitsbergen and every summer thereafter one or two Norwegian expeditions went to the island.

In 1907 and 1910 a large expedition set off under the command of Captain Isachsen, numbering, besides the leader of the expedition, nine scientists. Extending in all directions the survey made on behalf of the Prince of Monaco, they brought back maps of northwestern Spitsbergen between the northern coast, Wijde Bay, and Ice Fiord, of the region adjoining Green Harbor in the last-named fiord, and of Prince Charles Foreland.[4] During the two summers in which the expedition was in the field more than 2,000 square miles were mapped, and a great quantity of geological data was gathered.

From 1911 to 1918, under the leadership of Adolf Hoel and Captains Arve Staxrud and Sverre Rövig, topographical and geological surveys were extended to the peninsula between Ice Fiord and Bell Sound and southward to the coastal region as far as Horn Sound. The work of the Norwegians in Spitsbergen from 1906 until 1918 may therefore be summarized as follows:

All the western coastal region as far as a point lying three statute miles south of Horn Sound is now accurately triangulated and mapped in detail.[5] That is a piece of land about 200 statute miles long and 18 to 58 miles wide, covering 5,600 square miles. For the northern sheets the scale of 1:200,000 has been adopted, and for the southern sheets 1:100,000 and 1:50,000. All these maps will soon be published; a chart of the western coast of Spitsbergen, more nearly correct and more complete than the British and German charts, has already been published by the Norwegian Hydrographic Office.[6] In the coming years the survey will be continued southward; it is hoped to reach South Cape by 1922.

These expeditions also attained geological results of exceptional value. The chief points of interest about these re-

[3]The scientific results of the expedition are laid down in the splendid series of monographs published by the Prince of Monaco under the title "Résultats des campagnes scientifiques accomplies sur son yacht par Albert Ier. Prince souverain de Monaco," Fascicules 40 (surveys; with the map, 1:100,000, showing relief and glaciers in contours and shading, 41 (glaciology), 42 (geology and physiography), 43 (geology), 44 (botany).

[4]The geographical results are contained in:
Gunnar Isachsen: Travaux topographiques de l'expédition Isachsen, 1909-1910, *Kristiania Videnskapsselskapets Skrifter: I. Mat.-naturv. Klasse*, 1915, No. 7 (=pp. 1-63). [Contains the map of northwestern Spitsbergen in 1:200,000, showing relief and glaciers in contours.]
Idem: Green Harbour, *Norske Geogr. Selskaps Aarbok*, 1912-13, pp. 151-162. [With a map of Green Harbor in 1:100,000.]

[5]Besides the Norwegian surveys there should be mentioned the map of Prince Charles Foreland, 1:140,000, by Dr. W. S. Bruce and M. J. Mathieson, published in 1913 by the Scottish Oceanographical Laboratory of Edinburgh with the support of the Prince of Monaco.

[6]Spitsbergen: Farvand og Ankerpladser paa Vest-og Nordkysten, 1:200,000, with seven insets, Norges Geografiske Opmaaling Chart No. 198, Christiania, first edition, 1912.

WINTER HUT OF NORWEGIAN TRAPPERS AT SAFE HARBOR, NORTHERN SHORE OF ICE FIORD
(Photo by Dr. Holtedahl, 1909.)

TRAVELING OVER THE ICE FIELD TOWARD THE THREE CROWNS, THE THREE SUMMITS SEEN AT THE LEFT
(Photo by Captain Gunnar Isachsen.)

GENERAL VIEW OF THE COAL MINE AT LONGYEAR CITY

The mine lies on the western side of a small tributary valley entering Advent Bay from the south. The entrance to the mine can be seen high up on the hillside to the left with a cableway leading from it down to the harbor on Advent Bay in the center of the view. The houses at the foot of the slope are Longyear City.

searches are the study of the Devonian on the northern shores, the discovery of Quaternary volcanoes and of hot springs on the western shore of Wood Bay,[7] and the true determination of the age of the massifs of crystalline schists in the northwestern corner. These schists, ascribed to Archean, belong to the upper Heckla Hoek series (Silurian).

Besides these systematic expeditions, there were several others equally successful.

In 1908, Mrs. Hanna Resvoll-Holmsen made a botanical survey of the fiord region in West Spitsbergen. The same year and again in 1912 her husband, Dr. Gunnar Holmsen, carefully studied the numerous strata of fossil ice[8] whose existence in the soil of Spitsbergen was discovered in 1892 by the author of this paper.

GLACIAL FEATURES OF WEST SPITSBERGEN.

Thanks to the Norwegian expeditions, the peculiar glacial phenomena of West Spitsbergen can now be outlined. In the northwestern corner there is no ice sheet. The former inland ice, which had totally covered the region, has shrunk, and now alpine crests rise above the ice to heights of 4,200 feet and delineate great ice streams. But eastward from a line joining Cross Bay with the head of Wood Bay the alpine crests merge into ice-covered plateaus. As reckoned by Isachsen, the glaciated area in the coastal region extending from Smeerenburg Bay and Liefde Bay to Cross Bay is 67 per cent of the total area. On the other hand, the great peninsula between Ice Fiord and Bell Sound with large plateau massifs divided by wide valleys bears no arctic character. In that part of Spitsbergen the glaciation is only local. The large valleys are bare in summer and have boggy soils and meager pastures. Forty years ago numerous herds of reindeer were to be found there in autumn. Southward from Bell Sound and around Horn Sound there is a rugged land with large coalescing glaciers issuing from an ice sheet occupying the interior back of the high coastal crests.

[7]A. Hoel and O. Holtedahl: Les nappes de lave, les volcans et les sources thermales dans les environs da la baie Wood au Spitsberg. *Kristiania Videnskapsselskapets Skrifter: I. Mat.-naturv. Klasse,* 1911, No. 8 (=pp. 1-37). Adolf Hoel: Nouvelles observations sur le district volcanique du Spitsberg du nord, *ibid.,* 1914, No. 9 (=pp. 1-33).

[8]Gunnar Holmsen: Spitsbergens jordbundis og de bidrag dens undersokelse har kunnet gi til forstaaelsen av de i arktiske land optraedende varige isleier i jorden, *Norske Geogr. Selskaps Aarbok,* 1912-13, Christiania, pp. 1-132, with summary in German, pp. 133-150.

THE SURROUNDING SEAS.

The Norwegians have explored not only Spitsbergen, but also the surrounding seas. The first undertaking of this nature was the classic Norwegian deep-sea expedition headed by Mohn, Sars, and Danielssen which explored the Arctic Ocean from Iceland to Jan Mayen, Bear Island, and Spitsbergen (1876-1878). Later on, in 1900, Hjort and Nansen carried out a very valuable oceanographic cruise in the Arctic Ocean as far as Bear Island. In 1901, before starting on his Northwest Passage expedition, Roald Amundsen, on his celebrated *Gjöa,* investigated the oceanographic conditions around Spitsbergen.[9] During Isachsen's expedition in 1909 a great many vertical series of deep-sea observations were made.[10] Finally, in 1912, on his small yacht, Nansen investigated the waters of the western and northern coasts of Spitsbergen.[11]

The foregoing summary demonstrates the fundamental nature of the work the Norwegians have done in Spitsbergen. No other nation compares with them in their geographical discoveries, the number and accuracy of their surveys, and the extent of their scientific results in this archipelago.

INDUSTRIAL DEVELOPMENT—COLLIERIES.

With the twentieth century a new era begins in the history of Spitsbergen. Until then the archipelago had remained uninhabited, but during the past few years it has become a mining land and attracted a considerable number of Norwegian settlers. Coal deposits were long known to exist on the shores of Ice Fiord, but not until the first years of this century were they worked.

At present the best-developed collieries in Spitsbergen belong to Norwegian companies.

The Great Norwegian Spitsbergen Coal Company is working

[9]Fridtjof Nansen: Northern Waters: Captain Roald Amundsen's Oceanographic Observations in the Arctic Seas in 1901, *Kristiania Videnskapsselskapets Skrifter: I Mat.-naturv. Klasse,* 1906 No. 3 (=pp. 1-145).

Björn Helland-Hansen and Fridtjof Nansen: The Norwegian Sea: Its Physical Oceanography Based upon the Norwegian Researches 1900-1904 (Reports on Norwegian Fishery and Marine Investigations, Christiania, 1909, vol. 2, No. 2). [A standard work.]

[10]Björn Helland-Hansen and Fridtjof Nansen: The Sea West of Spitsbergen: The Oceanographic Observations of the Isachsen Spitsbergen Expedition in 1910, *Kristiania Videnskapsselskapets Skrifter: I. Mat.-naturv. Klasse,* 1912, No. 12 (=pp. 1-89).

[11]Fridtjof Nansen: Spitsbergen Waters: Oceanographic Observations during the Cruise of the "Veslemöy" to Spitsbergen in 1912, *Kristiania Videnskapsselskapets Skrifter: I. Mat.-naturv. Klasse* 1915, No. 2 (=pp. 1-132).

the most productive coal seams on the island on the western side of Advent Bay, which it bought in 1915 fom the Arctic Coal Company of Boston, Mass.[12] From 1909 to 1915 the total exportation of coal by the Boston company amounted to 150,000 tons. In the three following years it amounted to 85,000 tons.[13] This year (1919) the Norwegian company was also to start the exploitation of another coal deposit at Green Harbor.

The Norwegian Kings Bay Coal Company is working on the south shore of Kings Bay.

There are in addition four other Norwegian coal companies now beginning development. One has bought the holdings of an English company on the northeastern side of Advent Bay and will resume work this year. The capital invested in the six Norwegian collieries amounts to $4,200,000.

After the Norwegians come the Swedish Spitsbergen Coal Company, working on both sides of Braganza Bay (Bell Sound), and a Russian company working between Green Harbor and Coles Bay under the management of a Norwegian engineer.

The British are far behind, with two companies: the Scottish Spitsbergen Syndicate, headed by Dr. W. S. Bruce, and the Northern Exploration Company. Several years ago Dr. Bruce did some mining work on coal seams on Prince Charles Foreland, but nothing further seems to have come of it. The Northern Exploration Company has quarried a conglomerate which was taken for marble on the north shore of Kings Bay. This stone is said to be of little value, and it is asserted that none has been exported. The same company also claims an iron-ore deposit in Recherche Bay (Bell Sound) which is emphatically proclaimed to be one of the richest of the world. Scandinavian geologists who have studied this deposit are not of the same opinion. The Northern Exploration Company has recently undertaken preparatory work for mining coal on an island in Bell Sound.

SETTLEMENTS AND POPULATION.

Advent Bay is the chief population center of Spitsbergen. On its western side lies Longyear City, the most important settlement of the archipelago, and now belonging to the Great Norwegian Spitsbergen Coal Company. It offers very good accommodations, comfortable houses, electric light—the last very necessary indeed during the four months of long polar night. There are also a telephone system, well-stocked stores, and a hospital attended by a physician. In the summer of 1918 Longyear City numbered 300 inhabitants, all Norwegians. On the opposite side of the bay there is another Norwegian settlement, Hiorthaven.[14] Its population, entirely Norwegian, does not exceed 100 souls in summer and 60 in winter.

Besides these there are, on the southern shores of Ice Fiord, two small Norwegian hamlets, one on land owned by the Russian company between Coles Bay and Green Harbor, and another in Ice Fiord, near the coal deposits belonging to the Great Norwegian Spitsbergen Coal Company. On the southern shore of Kings Bay a large Norwegian settlement has been built near the Norwegian colliery, and on an island of the same fiord are some houses belonging to the Northern Exploration Company. In Bell Sound, besides small Norwegian hamlets on both sides of the fiord, there are in Braganza Bay a Swedish village near the Swedish mine and a British settlement on Axel Island.

During the past summer the Norwegian population of Spitsbergen amounted to about 800 souls.

COMMERCE AND COMMUNICATIONS.

Among Spitsbergen shipping the Norwegian flag takes first rank:

Since Mr. Longyear sold his settlement to a Norwegian company, the other flags are represented only by a few units.

In 1917 the general commerce between Norway and Spitsbergen attained its highest figure up to that time, $1,240,000; in 1918 it was probably much higher, owing to the increase of coal exports.

At Green Harbor the Norwegian Department of Telegraphs has erected a powerful wireless station communicating with a station at Ingö, near the North Cape of Norway, and at the Norwegian settlements of Longyear City and of Kings Bay and at the Swedish settlement in Braganza Bay secondary wireless stations are installed. A Norwegian postal service is established between Norway and Spitsbergen, with three postoffices, at Longyear City, Green Harbor, and Kings Bay. In 1918, from June to October, postal steamers made 26 voyages.[15] At the wireless station at Green Harbor a complete meteorological station is working whose observations are published in the *Jahrbuch des Norwegischen Meteorologischen Instituts.*

BEAR ISLAND.

A Norwegian company has also occupied Bear Island (Beeren Eiland). Lying 108 nautical miles southwards from the South Cape of Spitsbergen, this island is not so cold as Spitsbergen. Its annual temperature is —4.3° C. instead of —9.7° C. at Green Harbor, but the East Spitsbergen polar current, flowing westward, carries extensive drift ice all around the island. When the season is good, Bear Island is entirely ice-free for at least four months; in bad years the sea remains ice-strewn until July, but navigation is possible before that time.

At Bear Island coal occurs in the Devonian and Culm strata. Since 1916 the building of a settlement and installations for the working of coal deposits have been under way; so far the exports have been small. Eighty men wintered this year on the spot.

PREDOMINANCE OF NORWEGIANS IN SPITSBERGEN NAVIGATION.

The Norwegians have also had the largest share in the industrial development of Spitsbergen. Besides this, their acquaintance with the ice conditions for more than a century has, in a way, given them the monopoly of navigation in this archipelago, and nearly all the expeditions that have visited this Arctic land have engaged Norwegians as ice masters, frequently even entirely Norwegian crews. Thus, if the Norwegian Government should forbid its nationals to pilot foreign ships to Spitsbergen, nearly all maritime traffic between these islands and other lands than Norway would cease or become very dangerous.

POLITICAL HISTORY.

Spitsbergen is not a *"terra nullius,"* as it has been asserted. History establishes its rightful position.

At the end of the seventeenth century and for a long time afterwards Greenland was supposed to stretch northeastward and rejoin northern Russia by way of the Arctic Ocean. Barents himself and all his contemporaries were of the opinion that the land which he had discovered was part of a group of islands off the eastern coast of Greenland, and in this belief Spitsbergen was generally named Greenland until the beginning of the nineteenth century. Greenland belonging to the then united Norwegian and Danish crown, the King of Norway and Denmark accordingly claimed the ownership of Spitsbergen. This claim was also based on his generally accepted overlordship of the Arctic Ocean north and west of Europe, consequently of all the islands it contains wherever they might be and by whomsoever discovered.

In 1610 a number of whales in the western fiords of Spitsbergen having been seen by Jonas Poole, the news spread rapidly, and soon after numerous British, Dutch, French,

[12] Cf. *Geogr. Rev.*, vol. 7, 1919, p. 318.

[13] All the statistical data concerning the present economic status of Spitsbergen are taken from an official statement prepared by the Norwegian Government which will be issued several months hence.

[14] It takes the place of the former English mining settlement of Advent City, which no longer exists.

[15] During the fiscal year 1917-1918 the Green Harbor station received 2,041 telegrams and dispatched 3,323. It has intercepted 3,317 telegrams from other European and from American stations. In 1918, 10,322 letters, newspapers, and parcels were sent from Norway to Spitsbergen and 5,649 from Spitsbergen to Norway.

Danish, and Hanseatic whalers arrived at Spitsbergen. Among all these competitors troubles and disputes arose; even sea fights were not infrequent. The King of Norway and Denmark, Christian IV., protested against these incursions of his domain, and long diplomatic negotiations on the whale fishery and on the overlordship of Spitsbergen opened between the Norwegian-Danish monarch and the King of England, the States General of the Netherlands, the King of France, the Hanseatic cities, and the King of Sweden. These polar islands were the occasion of the first colonial conflict among European nations.

The King of England, James I, never expressly acknowledged the claim of Norway-Denmark regarding the sovereignty of Spitsbergen. Nevertheless in 1614 he offered to pay a rent to the Danish King, provided that English subjects should be granted a monopoly of the whale fishery in these islands together with the Norwegians and the Danes. Later on he suggested to Christian IV that he should sell him his right to "Greenland," that is Spitsbergen. The diplomatic transactions with England ended in 1621 by an agreement giving equal rights to English and Norwegian-Danish whalers in Spitsbergen. On the other hand, in 1632 the overlordship of the King of Norway and Denmark was accepted by the States General; however, a century later, in 1741, this acceptance was questioned by the Dutch. In 1663, 1679, and 1692, France, Sweden, and the Hanseatic cities respectively recognized the sovereignty of the King of Norway and Denmark over these polar lands.

Why has Spitsbergen today been declared *terra nullius?* During the second part of the seventeenth century, whales having deserted the coastal water of Spitsbergen, there was a cessation of the disputes regarding these islands. When two centuries later, in 1872, Spitsbergen again found a place in the minds of diplomats, the old transactions were totally forgotten, and the archipelago was proclaimed *terra nullius.* Only recently, in 1912, Dr. Arnold Raestad revived a knowledge of their history, basing his information on the state papers of Great Britain, Denmark, the Netherlands, and France.[16] Is there no such thing in regard to treaties as title by long possession? By inheritance of the Danish king's rights Norway possesses the sovereignty of the archipelago, but this sovereignty is not complete, not having been recognized by all the powers.

[16]Arnold Raestad: Le Spitsberg dans l'histoire diplomatique (translated from the Norwegian by Charles Rabot). *La Géographie,* vol. 25, 1912, pp. 335-354; vol. 26, 1912, pp. 65-98. The Norwegian original, "Norges hoihetsret over Spitsbergen i aeldre tid," Christiania, 1912, contains 47 original documents.

Higher Steam Pressures*

What Its Adoption Will Mean

IN theory it has long been established that there is everything to gain by the adoption of relatively high steam pressures, and practically nothing to lose. As long ago as 1896 Prof. R. H. Thurston made this abundantly clear in his paper on the "Promise and Potency of High-Pressure Steam." And since that time the science of thermo-dynamics having been more widely recognized by engineers as a sure guide to improvement of heat engine economy, the tendency to increase the temperature range of the working fluid has been more than ordinarily active.

But of these figures we have at the moment little concern; they merely lead the way to more practical considerations. They take us quite naturally up to that point where we begin to consider the ultimate possibilities involved in the adoption of much higher steam pressures. And here must we divide into two separate and distinct phases of treatment our lines of thought; for we shall have to consider (*a*) what the adoption of higher steam pressures would mean in the design and construction of boiler machinery, and (*b*) what it will mean in the design of those parts outside the boiler, and which are to be subjected to the proposed higher pressures and higher temperatures.

An Example of Present-Day Practice.—In the best present day practice, except for slightly higher pressures in some few isolated cases, the maximum steam pressure is 200 lb. per sq. in. absolute, the super-heat 200° Fahr. The corresponding temperature of evaporation is therefore 382° Fahr., the bulk of the heat being absorbed at a temperature 20° Fahr. below the maximum. An outside instance of the practical adoption of a considerably higher steam pressure than this is supplied by the 1,500 kw. turbine installation recently constructed by the British Thomson-Houston Co., in which a steam pressure of 350 lb. per sq. in. was employed together with a superheat of 700° Fahr., exhausting into a condenser of 28½ in. vacuum. As clearly illustrating the measure of economy obtained as a result of such increase of pressure and superheat, it was claimed that during a 10-hour full load test only 1.83 lb. of coal per unit generated was consumed.

This, perhaps, might well be considered a notable achievement in a twofold sense, inasmuch as such increase of pressure was accompanied with an almost unprecedented increase in temperature of the working fluid. Certainly it stood as an exemplification of far higher temperatures than had hitherto been employed outside experimental phases. But we will deal with this aspect of the case at a later stage.

Effect on Standard Boiler Design.—Assuming the employment of higher steam pressures to be justified what effect will this have upon standard boiler design? Present-day boiler designs and specifications do not permit the generation of steam at a pressure higher than 200-250 lb. per sq. in. without sacrificing safety, and without calling for an investment in the boiler plant high enough to offset the gain in economy caused by higher steam pressures.

Must all existing examples of boiler design be scrapped? Must all drums and steam vessels of large diameter, flat surfaces and even dished ends be abandoned—yes, even if stayed? Will all riveted, expanded or beaded joints exposed to the action of the fire have to go by the board? Will nothing but electrically welded joints permit such an increase as contemplated? Will the high-pressure generator of the future be cylindrical? Of the water-tube type? Or of the flash type? Is increased efficiency to be effected primarily along lines altogether different from those obtaining in boilers working under pressures used today? Or is it possible to retain present-day design and to increase the evaporation per sq. ft. of heating surface twice as high as that represented by the present-day practice?

These are questions involving much thought, demanding perhaps new and original channels of investigation, pregnant with possibilities. Who knows? Perhaps, after all, our best brains in the realms of engineering science, our efforts, our striving after heating efficiencies have been utterly misdirected, in that they have been conducted along altogether wrong channels. When an apparent limit has been reached in one particular direction often it is that a striking off at a tangent into the seemingly impossible will result in undreamed of achievement.

In view of the considerably higher temperatures involved in the production of these high steam pressures we have in

*Reprinted from *The Electrician* (London).

mind, and supposing the waste gases leave the boiler at a temperature of 700°-800° Fahr., will it not be necessary to conserve as large a proportion as possible of the heat units if efficiency is also an end in view? This will bring us to a new consideration of the functions and limitations of the economizer. Or might it be suggested tentatively that the waste gases, or at least a portion of them, might very profitably be used in a regenerative form to heat the air which supports combustion in the furnace?

Effect on Materials.—Passing from the boiler itself to outside constructional parts in the event of higher steam pressures being generally adopted, we find less insuperable difficulties barring the way. Pressures of from 600 to 800 lb. per sq. in. are not uncommonly met with today in internal combustion engine practice, as evidenced by the Diesel engine; higher even than these in compressed air and hydraulic installations. But it will not be pressure alone that will have to be taken into account in the matter of future design innovations; an increased superheat will mean infinitely more than any contemplated pressure increase. If we add 600° or 700° of superheat it is quite true that we shall effect a considerable saving, notably in pipe lines, seeing that higher velocities would be used, and that superheated steam has a much lower thermal conductivity than saturated steam. But what of the boiler fittings and valves, the blading at the high pressure end of impulse turbines? In the latter connection the proposed increase of pressure might well be compensated for by increasing the thickness of the walls, by substituting steel for cast iron, but very much higher temperatures will necessitate the adoption of a special heat-resisting steel alloy for the blades at the high-pressure end of the turbines. Or it may well be that much of the difficulty in this direction will be got over by the employment of cross compound types of turbine, such as are employed in marine work, each turbine driving a separate generator, the change of temperature in each unit being thus considerably reduced.

High Pressure and Reciprocating Engines.—With such increase both of temperature and pressure, reciprocating engines of the double flow type must, because of their excessive condensation losses at the period of steam admission, and to heat transference between the steam and the cylinder walls, give place to the uniflow type of piston engine. But as against the adoption of the latter must be set the fact that it is impossible to carry expansion down to the condenser pressure; this is a factor that will need thoughtful consideration. But might it not be got over by operating it as a non-condensing engine, utilizing the heat from the exhaust in the feed water?

It is a debatable point whether the future will see cast iron holding its present position in the constructional details of steam engines. Many cases can be cited of casting failures where the final temperatures of the steam was only 500° Fahr., while on the other hand there are doubtless many plants using superheated steam of a temperature even higher than this, equipped with nothing but cast iron fittings and valves.

Some authorities hold that providing the cast iron contains a large proportion of steel in order to give it the necessary strength to resist the greater expansion strains involved, and is low in silicon content, there is little need for the employment of cast steel in the event of any reasonable high temperatures being adopted. But doubtless this assumption would have been based on present-day practice, and would not therefore hold good for the very much higher temperatures now in contemplation.

In piston engines of the double-acting type the question of cylinder lubrication will be all important in the event of higher steam pressures and increased superheat. It is questionable if the advent of pressures of from 400 lb. to 600 lb. per sq. in., together with a superheat of from 500° to 800° Fahr. will permit of the use of either slide or Corliss valves. The packed rod might also present insuperable difficulties. This then would lead us inevitably to the consideration of the single-acting type of engine; perhaps from the point of view of weight per horse-power and efficiency, the only logical design for these higher pressures.

Also important in piston engines is the question of cylinder lubrication. The greater proportion of the lubricating oil now used in piston engines is required for the steam distributing valves; that actually required by the piston and piston rings being comparatively small. Consequently, the possibility of sufficient piston lubrication is not affected by higher initial steam pressures, because even in case of very high mean effective pressures in single-acting engines, where the piston serves as crosshead, and therefore requires constant lubrication, the piston can be made sufficienty long to keep the pressure per square inch within safe limits.

It thus seems clear that if we increase steam pressures to say 500 lb., or 600 lb., per sq. in. without using temperatures much higher than those employed in modern practice, the more radical changes in design will be those requiring to be effected in the steam generator. But if we increase in the same proportion the existing degree of superheat—and this seems almost essential if the fullest advantages are to be obtained—then must the changes in design be much more comprehensive; and will exercise to the utmost the skill and judgment of engineers and power plant designers.

EFFECT OF DECAY ON WOOD PULP.

CLEAN groundwood pulp and pulp infected with molds and fungi have been used in recent comparative paper-making trials at the Forest Products Laboratory. These trials showed that infected pulp was inferior to clean pulp in the following respects:

The infected pulp produced a very dirty sheet. It required more sizing than the clean pulp. It stuck to the couch and press rolls and gave trouble from excessive foaming.

Although groundwood pulp is usually considered too slow, the extreme freeness of the infected pulp caused difficulty in carrying the necessary amount of water on the paper machine to secure a good formation in the finished paper.

Based on the percentage of groundwood, the infected pulp used in the experiments yielded 10 per cent less finished paper than the clean pulp.

The strength of the finished paper was greatly reduced by the use of infected pulp. In a groundwood sulphite finish, this decrease in strength would necessitate the use of a larger percentage of the more expensive sulphite pulp.

KILN DRYING OF GREEN HARDWOODS.

SUCCESSFUL kiln drying of hardwood lumber green from the saw necessitates a very even control throughout the kiln at all times. This means that variations in temperature of even a few degrees or variations in relative humidity of 5 to 10 per cent are seldom permissible. Such uniformity is possible only when the heating coil is properly drained, is relieved of air, and is distributing heat uniformly along its length.

It is the contention of the Forest Products Laboratory that the return-bend heating coil system, by bringing about more uniform distribution of heat in the kiln, enables the operator to obtain quicker and better drying than is possible with the header-coil system, as it is generally installed.

The return-bend heating coil gives a practically even heat distribution under any steam pressure. The header-coil produces different temperatures at either end of kiln, the extent of variation depending on the steam pressure, length of coils, drainage, traps, etc.

Refractory hardwoods require low temperatures, and the lower the temperatures used, the more evident will be the difference in the results obtained with these two types of heating equipment. Under the same careful operation, green hardwood lumber may be turned out from kilns using the one type satisfactorily dried, and from kilns using the other type checked and overdried at one end and molded and underdried at the other end.

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WHAT is now known as the Bonecourt system of surface combustion embodies the practical results of certain discoveries made by one of us during scientific researches upon the influence of hot surfaces in promoting gaseous combustion. It is recognized nowadays by all chemists that chemical interactions in gaseous systems are promoted by the catalytic action of hot surfaces, and the case of gaseous combustion is no exception to this general law. The researches referred to proved that, if an explosive gaseous mixture be either injected on to or forced through the interstices of a porous refractory incandescent solid, under certain conditions, a greatly accelerated combustion takes place within the interstices or pores: or, in other words, within the boundary layers between the gaseous and solid phases wherever these may be in contact and that the heat developed by this intensified combustion would maintain the surface in a state of incandescence without any development of flame, thus realizing the conception of flameless incandescent surface combustion, as a means of greatly increasing the general efficiency of heating operations wherever it can be conveniently applied.

Perhaps the simplest illustration of this system of flameless incandescent surface combustion is afforded by the diaphragm method of applying radiant heat, and it was obvious from the first that important results would accrue if by any means it could be successfully applied to the raising of steam in gas-fired boilers.

It will probably be generally admitted that up to a few years ago the gas firing of steam boilers had not been very successful from the point of view either of thermal efficiency or rate of evaporation. The low thermal efficiency of boilers fired in the ordinary way by blast furnace gas is notorious, while even in the case of boilers fired with coke oven gas the thermal efficiency probably did not much exceed 65% or 70%.

The first experiments made in the year 1909 by the late Mr. C. D. McCourt and one of us upon the application of the principle of surface combustion to the gas firing of multitubular boilers, proved the possibility of transmitting between 90% and 95% of the net calorific value of coke oven gas to the water in the boiler. The nature of these early experiments has already been dealt with so often in public that it will be unnecessary for us to enlarge very much upon them. Suffice it to say that the first experiment in Leeds was made with a single steel tube 3 ft. in length and 3 in. in diameter, packed with fragments of granular refractory material, meshed to a proper size, and fitted at one end with a fireclay plug through which was bored a circular hole ¾ in. diameter, for the admission of the explosive mixture of gas and air at a speed greater than that of back-firing.

Experimenting with such a tube, it was found possible to burn completely a mixture of 100 cub. ft. of coal gas plus 550 cub. ft. of air per hour, and to evaporate about 100 lb. of water from and at 100° C. (212° F.) per hour (20—22 lb. per sq. ft. of heating surface), the products leaving the further end of the tube at practically 200° C. This meant the transmission to the water of 88% of the net heat developed by the combustion, and an evaporation per sq. ft. of heating surface nearly twice that of an express locomotive boiler. The combustion of the gas was completed within 4 or 5 in. of the point where it entered the tube. Of the total evaporation, no less than 70% occurred over the first linear foot of the tube, 22% over the second foot, and only 8% over the last foot. This pointed to a very effective "radiation" transmission from the incandescent granular material in the first third of the tube, where the one of active combustion was located, although it should be remarked that the loci of actual contact between the incandescent material and the walls of the tube were so rapidly cooled by the transmission of heat to the water on the other side that they never attained a temperature even approaching red heat. The granular material in the remaining two-thirds of the tube served to baffle the hot products of combustion and to make them repeatedly impinge with high velocity against the walls of the tube, thus materially accelerating their cooling, and either preventing or minimizing the formation of the feebly-conducting stationary film of relatively cold gases which in ordinary practice clings to the tube walls, seriously impairing the heat transmission.

From this initial experiment Bone and McCourt proceeded to construct their first experimental boiler (Fig. 1) which was made of ten such tubes fixed horizontally in a cylindrical steel shell capable of withstanding a pressure of over 200 lb. to the sq. in. This small boiler was connected with a small tubular feed water heater containing 9 tubes, each 1 ft. long and 3 in. diameter, similarly packed with granular material to facilitate the exchange of heat.

With this simple combination of boiler and feed water heater we were able to transmit to the water 93.3% of the net heat units contained in London coal gas of 510 B.T.U. net per cub. ft. at N.T.P. and obtain an average rate of evaporation of as much as 33.9 lb. water per sq. ft. of heating surface per hour (from and at 212° F.); the steam gage pressure was 103 lb. and the products of combustion left the feed water heater at a temperature of 289° F.

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through a short mixing tube, into each of the said combustion tubes where it was burnt without flame in contact with the incandescent granular material. After leaving the boiler tubes the products of combustion passed onwards into a semi-circular chamber at the back of the boiler, into a tubular feed water heater and from thence they were drawn by the fan which discharged them at a temperature of 95° C. into the atmosphere.

In a series of independent trials carried out on the plant by an eminent American steam engineer in July, 1912, it was found that, even when the boiler was not lagged and when it was raising steam at a pressure of 100 lb. above that of the atmosphere, 92.7% of the net heating value of the coke oven gas was transferred to the water and sent out as steam, the overall evaporation being at the rate of 14 lb. per sq. ft. of heating surface per hour (see Table 2).

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Results of Steam Trial.

July 29th, 1912.

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Mean steam gas pressure in lb. per sq. in. above atmospheric	97·2
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Evaporation in lb. per sq. ft. of heating surface per hour	14·1
% of dryness of steam	99·3
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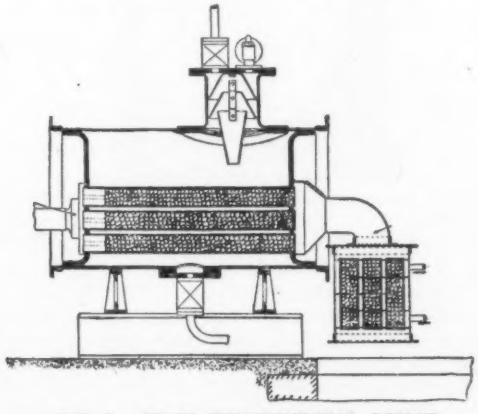
As is often the case, the first attempt to translate a new idea of this kind into everyday large-scale practice was not unattended with difficulties, the investigation of which has taught us certain valuable lessons. There was no difficulty whatever with the Skinningrove boiler or boiler tubes, or with the gas feeding arrangements. Notwithstanding the high evaporation, the mechanical properties of the tubes were not



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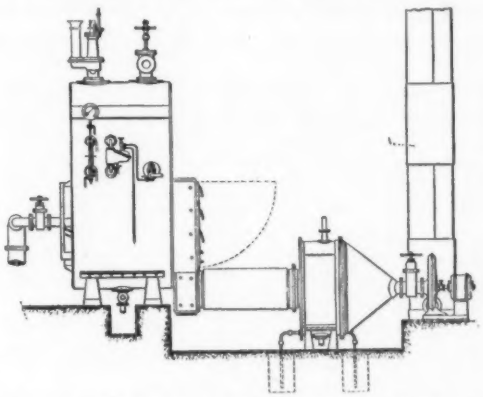
The average temperature of the products leaving the boiler when evaporating at a gage pressure of 95 lb. to the sq. in. was about 195° C., or only 28° C. above the temperature of the steam. The effect of the feed water heater first installed was to reduce this temperature to practically 95° C., which was too low to prevent corrosive action. According to our experience, 120° C. is the lowest limit to which the temperature can be reduced without the risk of corrosive action upon the fan, and to allow a sufficient margin of safety at light loads it would be preferable not to reduce it below 130° C.

As there was no superheater, the work which could be done by the feed water heaters in reducing the products from 195° C. to 130° C. was so small that it was decided, in altering the Skinningrove plant, to cut out the feed water heater altogether and to substitute fans running at a lower speed, and fitted with water-cooled oil ring lubricated bearings on account of the higher temperature of the products to be dealt with, and this has been done. The efficiency of the plant, now that the boilers are lagged, will still be about 90% on



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the net calorific value of the gas supplied, even without the feed water heater.

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Several other boilers of the Skinningrove type, with certain modifications in the packing and burners, and reduced suction, have been installed by the Bonecourt Waste Heat Boiler Co., Ltd., London, on the mains of the South Metropolitan Gas Company and the Gas Light and Coke Company. From a technical point of view we are still prepared to erect large boilers of the modified Skinningrove design for coke oven or coal gas, and to guarantee their high thermal efficiency and smooth working, but as the result of more recent developments in regard to the structural features of the boiler, we would now recommend one or other of the types to be described presently, which have been duly protected by patent applications.

Although a boiler with 100 or more tubes, each 4 ft. long by 3 in. diameter, packed with loose fragments of a suitable granular refractory material, as in the case of the Skinningrove boiler, is eminently suitable for use with a perfectly dustless and tarless gas, such as coke oven gas, it is preferable, when dealing with gases which are liable to contain dust or tar, to substitute a special rigid system of refractory surfaces (Fig. 3) over which the combustible mixture sweeps and in contact with which it is burnt at a highly accelerated rate. This has enabled tubes of much greater length to be used, which has the advantage of reducing the diameter of the boiler, reducing the number of burners, and reducing the cost of construction for a given evaporation. A further ad-

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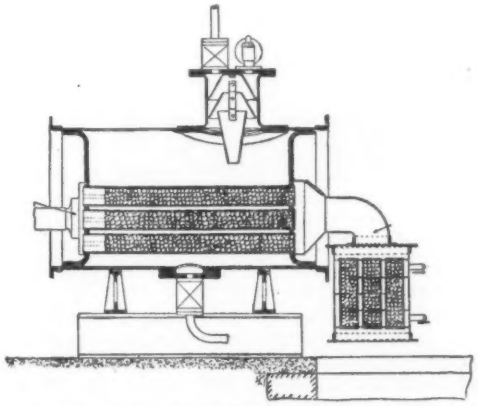

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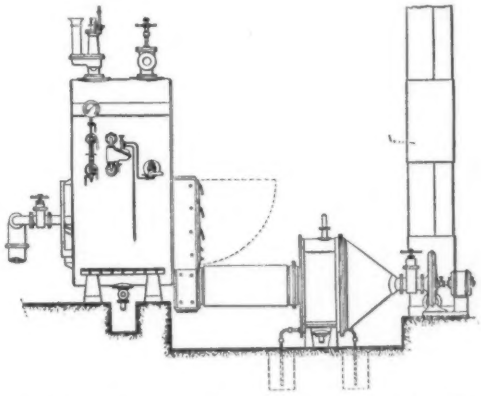

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BOILERS WITH RIGID BLOCK PACKING FOR PRODUCER GAS.

Several other boilers of the Skinningrove type, with certain modifications in the packing and burners, and reduced suction, have been installed by the Bonecourt Waste Heat Boiler Co., Ltd., London, on the mains of the South Metropolitan Gas Company and the Gas Light and Coke Company. From a technical point of view we are still prepared to erect large boilers of the modified Skinningrove design for coke oven or coal gas, and to guarantee their high thermal efficiency and smooth working, but as the result of more recent developments in regard to the structural features of the boiler, we would now recommend one or other of the types to be described presently, which have been duly protected by patent applications.

Although a boiler with 100 or more tubes, each 4 ft. long by 3 in. diameter, packed with loose fragments of a suitable granular refractory material, as in the case of the Skinningrove boiler, is eminently suitable for use with a perfectly dustless and tarless gas, such as coke oven gas, it is preferable, when dealing with gases which are liable to contain dust or tar, to substitute a special rigid system of refractory surfaces (Fig. 3) over which the combustible mixture sweeps and in contact with which it is burnt at a highly accelerated rate. This has enabled tubes of much greater length to be used, which has the advantage of reducing the diameter of the boiler, reducing the number of burners, and reducing the cost of construction for a given evaporation. A further ad-

vantage is that the amount of suction required has also been considerably reduced.

The use of this new rigid system of refractory packing has also reduced the maximum temperature produced on the packing surfaces in the front part of the boiler to a degree certainly below 1,000° C., and probably to about 850° C. This has been done by facilitating the heat transmission to the water by free radiation from the whole of the packing surfaces to the tube walls. As an illustration of these newer types of boilers we may describe the constructional features of two boilers erected in the year 1914 in the Birmingham district for generating steam from gas made in Kerperley producers.

These boilers are each 10 ft. diameter by 12 ft. long; each unit contains 38 tubes, 6 in. diameter, packed with the special rigid system of molded refractory blocks. Each of the tubes is provided with its own gas supply, which can be easily reg-

FIG. 3. RIGID SYSTEM OF REFRACTORY SURFACES

ulated by means of a wheel-valve on the boiler front, while the air requisite for combustion, together with a regulated proportion of gas, is drawn into each tube, through a short mixing chamber, by the suction of an electrically driven fan situated at the back of the installation. Each unit will evaporate up to 15,000 lb. of water from and at 100° C. per hour. The combustion in the tubes is perfect, and when operating at a gage pressure of 85 lb. per sq. in. the products leave the system (there being no feed water heater included in the installation) at less than 250° C.

These two boilers, it may be said, have been running continuously for nearly five years, and no tubes have yet had to be renewed in them.

The only criticism which we have to pass as the result of experience gained in working them, and which led us to adopt further modifications, is that we did not consider that a burner system which involved the use of separate wheel valves for each tube of the boiler could be regarded as finality, and that it would be an advantage, from the point of view of evaporative power, if by any means tubes of smaller diameter and still greater length could be adopted in order to increase the heating surface.

The next step was an important improvement in the design of the burner which has enabled us to dispense entirely with separate control for each boiler tube and to feed a whole nest of tubes from a gas-box controlled by one valve. The elements of this design are shown in Fig. 4. The illustration of this newest burner shows a gas chamber controlled by one valve capable of supplying gas to a nest of 26 boiler tubes. The gas is fed into chamber from a main on which there is a cock controlling the pressure in the gas-box. The front of the box is bored with a number of holes, of the correct size, each of which is immediately opposite the axis of one of the boiler tubes. These holes are of uniform bore, but their diameters are adjusted by a rimer in such a way that with a given gas pressure in the box each delivers exactly the correct quantity of gas to each boiler tube even when that quantity may vary slightly in different tubes. Hence the quantity of gas admitted to each tube depends simply upon the pressure in the box which is controlled by the single valve referred to. While the quantity of gas is controlled by the gas pressure, the air is controlled by the fan, and all the operator has to know is how to vary the two together for different loads, which information is given him by the company's expert when the boiler is first put into commission.

BOILERS WITH SPIRAL PACKING.

In one small boiler operating on London coal gas with natural draught fitted with such a feeding chamber there are 26 tubes, each 2 in. diameter, and 4 ft. long. Each tube is fitted with an iron packing of spiral form, the front part of which becomes red-hot and acts as the catalyzing surface for the combustible mixture, and so completes the combustion flamelessly in the first foot of the boiler tube. The products of combustion sweep through the system in a spiral motion and rapidly give up their sensible heat to the water.

EXPERIMENTS UPON SUPERHEAT.

During the early stages of the development of our designs we were concerned mainly with the problem of evaporation and heat transmission. The important subsidiary problem of superheat was left until later. It was of course recognized that it would be impossible to develop the system for large power station work where high superheats are required unless a satisfactory solution of the subsidiary problem had been arrived at. During the war the problem was tackled on an experimental scale, with results which have enabled the boiler design to be modified so as to provide for superheats up to the highest degree required in modern power station practice. As these experiments were begun at a time when we were using tubes of 6 in. diameter, the well-known and well-tried locomotive type of superheater adapted for insertion in flue tubes of 5½ in. diameter or thereabouts was first tried.

In the first experimental arrangement a tube 13 ft. long and 6 in. diameter was packed for the first 4 ft. of its length with the aforesaid rigid block packing, for the next 6 ft. with a superheater element, and for the remaining 3 ft. with a specially shaped packing. The tube was fitted into a boiler shell 18 in. diameter suitable for a working pressure of 100 lb. to the sq. in. The gaseous mixture was burnt and the temperature of the products reduced to 1,300° F. (about 700° C.) before reaching the superheater element, and, after leaving the latter, the sensible heat remaining in the products was rapidly given up to the water in the boiler. By means of this arrangement steam at 100 lb. pressure was superheated

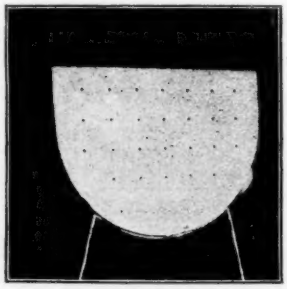


FIG. 4. GAS CHAMBER SUPPLYING 26 BOILER TUBES

192° F. to a total temperature of 530° F., while at the same time the temperature of the products leaving the system was reduced to 442° F., which was only 104° F. (58° C.) above the temperature of the saturated steam in the boiler. No feed water heater was attached in this experiment. In another experiment a superheat of 340° F. was obtained; the total temperature being 678° F., but in this case the temperature of the products leaving the system rose to 500° F., or 162° F. (90° C.) above that of the saturated steam in the boiler.

The improvements already described in the burners of the boilers, and the return to tubes of smaller diameter made it advisable to discard the locomotive type of superheater in favor of a modified type of that commonly used in Lancashire boilers.

Finally a complete unit, as shown in Fig. 5, comprising the boiler, burners, superheater, feed water heater and fan, all on one foundation, has been designed. The boiler itself is 6

ft. diameter by 18 ft. long. There are two nests of tubes which are packed with the iron spiral packing already referred to. Each nest is fired from one burner-box and controlled by one valve. The packing of the tubes is so arranged that the products of combustion will pass from the boiler to the superheater at a temperature of 500° C., more or less according to the amount of superheat required, while the sensible heat contained in the gases leaving the superheater is recovered in the feed water heater, the temperature of the gases being reduced to 130° C. in the feed water heater, at which temperature they enter the fan. Such a combined arrangement of boiler superheater, and feed water heater in one unit has the advantage that it allows of a greatly increased evaporation in the boiler itself per unit of heating surface as compared with the former arrangement of boiler only, and, so far as can be estimated from our experiments, this small boiler would easily evaporate 20,000 lb. water from and at 212° F. per hour when supplied with coke oven gas, and 15,000 lb. from

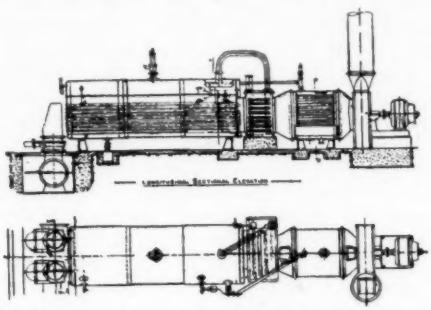


FIG. 5. COMBINED ARRANGEMENT OF BOILER SUPERHEATER AND FEED WATER HEATER IN A SINGLE UNIT

and at 212° F. per hour when supplied with producer gas. In either case the suction would not be more than 9 in. of water, and the overall thermal efficiency would be the same as in the original Skinningrove unit.

As the pressure at which steam is generated in modern central power stations is rapidly increasing it is interesting to note that the boiler shown in Fig. 5 can be made out of ordinary plate for a working pressure of 450 lb. to the sq. in.

Objections sometimes put forward against shell boilers are not applicable to the Bonecourt boiler as, like the shells used in water-tube boilers, they are neither subjected to contact with the hot gases, nor used as part of the heating surface. Moreover, unlike some water-tube boilers, the shell plates are not drilled to accommodate tubes. They have the great advantage over water-tube boilers in that there is no internal pressure tending to burst the tubes. The tubes are floated by the water, and as the water can flow to the heating surface over the whole length of the tubes instead of only at one end, the boilers can be forced in an extraordinary manner without risk of priming or of burning the tubes out.

In water-tube boilers it is common practice to couple a number of shells in parallel. In the Bonecourt boiler, not only can drums be placed side by side, but also one above the other and yet controlled by a single set of steam fittings. From these remarks it will be seen how easy it is to make a Bonecourt multi-drum boiler for almost any output and for any desired pressure and superheat, the space occupied being far less than that of any other boiler. Back-firing is impossible, and there are no large combustion chambers in which dangerous explosions can occur.

WASTE HEAT BOILER DEVELOPMENT.

In addition to the development of surface combustion boilers described in this paper, considerable progress has been made commercially with the installation of waste heat boilers in various parts of the kingdom, for the generation of steam from the hot products of combustion discharged from internal combustion engines and industrial furnaces.

"BLUE-SHORTNESS" AND AGEING OF IRON.

H. FETTWEIS attempts in *Stahl w. Eisen* a comprehensive explanation of "blue-shortness" and the ageing of iron and steel, based on the following theory:

By working the material at temperatures below 500 deg. C. a transformation is set up, which may be termed "ageing." This "ageing," which tends to intensify the effect of cold-working, requires months and years to develop at ordinary temperatures, but takes place more quickly with a rise in temperature, so that it may even develop in fractions of a second and so cause the phenomena of blue-shortness. From about 100 deg. C. onwards the consequences of ageing are weakened by the effects of reheating or tempering the metal, which effects are more pronounced the higher the temperature.

Based on this theory, it is possible to throw light on the following phenomena:

(1) In strength tests carried out on that material, a minimum value of the tensile strength is found at 80° C., and a maximum between 200° and 300° C., in the case of tensile tests carried out at ordinary speed. When the speed of test is increased, the curve showing the strength in terms of temperature is displaced in the direction of the higher temperatures. The yield-point gradually falls with increasing temperature. The resistance of iron to repeated impacts also shows value between 200° and 300° C. whereas the minimum notch-impact strength as determined by a single blow lies between 400° and 500° C.

(2) If iron is worked at temperatures below 500° C., and afterwards tested at room temperature when cold, a maximum and minimum respectively for all the strength properties of the material is found between 200° and 300° C. The tensile strength minimum at 80° C. disappears.

(3) The same results as in (2) are attained when the material is worked cold and then heated to a higher temperature for not too long a time.

(4) In order to bring about the above-mentioned changes in iron, which are characteristic of "blue-shortness," it is not necessary to heat it, but it is sufficient to have the cold-worked material lying at ordinary temperatures for some time, *i. e.*, to allow it to "age."

(5) If completely aged iron is reheated to different temperatures, then on afterwards testing the material it is found that all the strength properties gradually fall or rise with increase in the reheating temperature, without, however, showing a maximum or minimum value.

STEAMSHIP SUNK BY SUBMARINES TO EXTINGUISH A FIRE.

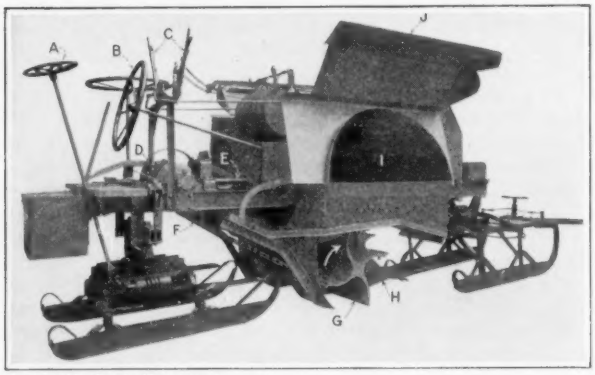
THE most spectacular and costly marine accident which has occurred at the Panama Canal since it has been in operation, resulted from an explosion in the hold of the American steamship "Marne" on the afternoon of January 24, while she was reloading part of her cargo at pier 11, Cristobal. The explosion was immediately followed by fire. In the cargo was 160,000 cases gasoline and benzine and in her tanks about 1,700 tons of fuel oil. The fire of this inflammable material being beyond the control of the terminal fire engines and fire tugs, the ship was towed away from the pier and sunk in shallow water. The great heat made it impossible to sink the vessel by opening cocks below the water line and she was sunk by shots from two of the Navy submarines. Fifty-four shots were fired from 3-inch guns. Armor-piercing shells were used first, fired into the vessel amidships. The holes they made were not large enough to admit water rapidly, and about six shrapnel shells were fired into the stern which pierced the hull and the "Marne" settled and sank in about 40 feet of water, inside the breakwater, about a mile from the outer end. After sinking, her decks were awash and the oil floating on the top continued to burn. Cases of gasoline and benzine on fire floated away from the ship and spread out over the harbor for a distance of half a mile. At night, these were a lurid and unusual sight.—From *The Panama Canal Record.*

Clearing Canadian City Streets of Snow*

Horse-drawn, Power-operated Snowplow

A POWER-OPERATED rotary snowplow hauled by horses is a new development in machinery equipment for cities where removal of snow is a serious and annual problem. Such a machine is being used on streets, suburban roads and sidewalks in some Canadian cities with satisfactory results as to both efficiency and economy. The general design is shown in Fig. 1, while our frontispiece shows a rear view of the machine in use. In Fig. 2 the plow is shown working on a sidewalk in a residential district. Its weight is about three tons and its length is 18 ft. over all.

Swiveling sleds carry a steel frame 14½ feet long, the team being hitched to the forward sled and the rear sled being steered by means of a handwheel. Upon the frame is mounted a 60-h.p. gasoline engine, having its shaft placed longitudinally and geared to a cross shaft at the rear. This shaft has a sprocket wheel for chain drive to a shaft hung below the frame and carrying two rotary cutters. The cutter shaft can



Courtesy of Engineering News-Record

FIG. 1. ROTARY PLOW FOR STREETS AND ROADS, MOUNTED ON SLEDS AND HAULED BY TEAMS

A—handwheel for steering rear sled; B—Handwheel for regulating height of cutter shaft; C—Engine levers; D—Sprocket wheel; E—Engine shaft; F—Driving chain; G—22-in. cutter; H—Nose of wedge plow; I—Discharge opening; J—Snow deflector.

be raised and lowered in order to vary the depth of cut as may be required. The four-bladed cutters mounted on this shaft are 22 in. in diameter, 22 in. wide and 22 in. apart, a wedge-shaped plow being placed in front of the space between the two cutters so as to deliver the snow to them. Thus the total width of cut is 5½ ft. The snowplow is carried by the frame of the cutter shaft and is thus raised and lowered with it.

The cutters are driven at a speed of 500 r.p.m. and discharge the snow as a finely divided dust through deflecting hoods on one or both sides of the machine, the maximum width over these being 6½ ft. The deflectors are adjustable, to enable the snow to be delivered at about 3 or 4 ft. from the machine in streets or thrown to a distance of 40 to 50 ft. on suburban roads. Thus no snow is thrown against buildings or windows along the streets. In the suburban districts the residences are set back from the street, so that the snow from the roadway and sidewalks is thrown over the lawns. No objection is raised to this, as the snow is spread and does not form banks. In widening the first 5½-ft. cut, or in operating along street railway tracks, the machine is offset so as to be crowded into the solid snow while the horses travel in the cut already cleared.

Four or six horses are used, but the machine can be attached to a tractor or truck. The draft is not heavy, as only the forward sled has to break through the snow and this will go through a 36-in. depth without trouble, while the rear sled travels in the cleared path. The machine will work in snow up to 6 ft. deep, as in the case of drifts. It leaves a bed of snow beneath it so that sleigh traffic is not interfered with, this bed being usually 4 in. to 6 in. deep on municipal work.

In a test at Westmount, Que., under the direction of P. E. Jarman, city engineer, the work was to remove and distribute heavy compacted banks which had been formed by pressing back the snow from the middle of the roadway with the blade of a snow grader. Mr. Jarman gives the cost as $35.70 per 1,000 cu. yd. This included operating charges for four horses, two drivers, a mechanic, gasoline, oil, grease and repairs; also charges for depreciation, interest and insurance. Removal by hand shoveling would have cost $53.80 per 1,000 cu. yd. Further, Mr. Jarman points out that the men would have piled the snow in high banks while the machine spread it in a thin layer. As a result of the test and other experience the city purchased one of the rotary plows.

At Outremont, Que., which also has a machine, careful study of the cost was made by J. Duchastel, city engineer, and E. Lacroix, assistant city engineer. In three days (23 working hours) the machine cleared a 10-ft. path in snow 21 in. deep for a distance of 6,775 ft. at a cost of 7.2c per lin. yd., or 3.7c per cu. yd. This included fixed charges of $14 per day for repairs, 7 per cent interest and 10 per cent depreciation; also gasoline, operator, two city teams and the cost of a grader and single plow used in connection with the work. In comparison with this was the removal of snow by hand shoveling into wagons on sleighs, on a stretch of 950 ft. of the same road,

Courtesy of Engineering News-Record

SIDEWALKS BEING CLEARED BY ROTARY PLOW WHICH THROWS THE SNOW ON THE LAWNS

with the same depth and width of cut, at a cost of 23.7c per lin. yd., or 12c per cu. yd. This was done in a 10-hour day by 14 men at 25c per hour, a foreman at 35c, a city double team at 65c, three hired double teams at 60c, and four hired single teams at 30c. Sidewalks made impassable by drifts were cleared by the machine at about 50 per cent of the cost of hand shoveling. Here, as at Westmount, the advantage was noted for distributing the snow evenly in a thin layer instead of forming banks.

Hand shoveling on a mile of road at Levis, Que., cost $1,979 during 35 days' work from Dec. 26, 1918, to March 12, 1919, with from 6 to 21 men. From the figures of the work at Outremont it was estimated by H. E. Weyman, superin-

*Reproduced by courtesy of *Engineering News-Record*.

tendent of the Levis Street Railway, that this could have been done with the rotary plow at a cost of $396. On the basis of his investigation the railway company purchased a machine.

It was estimated that the machine could remove snow for a cut 5 ft. wide, 4 ft. deep and a mile long at a cost of $20.79, this being distributed as follows and being exclusive of interest and depreciation: four horses at $1.50, $6; two men at $3.50, $7; gasoline, $6; oil, $1; insurance, 79c. Hand work would require 24 men at $3 per day, which with an insurance charge of $8.13 would make a total of $80.13. On four miles of road at Levis, where the snow was shoveled back and not carted away, the cost of hand work last winter was $3,000. If the machine had been available the operating cost would have been about $750. Adding $810 for interest and depreciation the total would have been $1,560, or very little more than 50 per cent of the cost of hand labor, while the work would have been done in much less time.

Practical Applications of Selenium—III*

Its Utilization in Tele-Mechanics

By Louis Ancell

ONE of the most interesting applications of selenium consists in controlling the draft of factory chimneys by means of this method. In this case the material is reduced to its simplest expression: namely, a selenium cell placed in a cavity within the chimney located at a point where the temperature is not very high and the deposit of soot is as slight as possible; in a second cavity diametrically opposite to the cell there is an incandescent lamp designed to illuminate the cell (through the smoke). The lamp and the cell are protected from the smoke and gases by panes of glass (placed so as to be readily accessible for cleansing) which are so arranged as to avoid the action of the heat upon the selenium.[1] The cell is connected with an accumulator and with a recording milli-ampere meter placed in the office of the engineer or the foreman in charge of the forge. A mere inspection of the curve of the recording apparatus indicates immediately whether the smoke is more or less damp and consequently enables the person in charge to control at any moment the operation of the furnace and the draft of the chimney.

CONTROLLING THE RAPIDITY OF THE MANUFACTURE OF SULPHURIC ACID

Another interesting application is intended to govern the rate of speed of the manufacture of sulphuric acid in the contact process. One of the conditions required for proper functioning is the absence of sediment in the reaction tube; it is only necessary, therefore, to place a selenium cell at one end of the tube and an incandescent lamp at the other; a recording galvanometer, connected with the accumulator and with the cell enables the operator to observe the varying transparence of the atmosphere of the tube and thus to have a permanent control, the recording apparatus which is placed in the office of the operator.

APPLICATIONS TO THE MILITARY ART.

The applications of selenium to the military art are as numerous as they are varied, and the long war which has just come to an end with the victory of our arms, has enabled us to demonstrate some of the most original properties of selenium. I, myself, pointed out its importance at the beginning of the war.[2] I shall here mention only the most interesting of these applications.

To begin with wireless telephony by means of selenium and luminous waves was employed on the French front for various experiments, for which the cells were furnished by me. Furthermore, this process seems to have been employed by the Austrians upon their Alpine front, shortly after the entrance into the war of Italy. The description of this process will be given farther on. The restricted range (15 to 20 km.) and the necessity of having a rather cumbrous equipment limited the use of this system of communication, which was soon replaced, moreover, by ground telephony and by vacuum tube telephony.

TELE-MECHANICS.

We may also mention among the military applications those concerned in tele-mechanics, with the liaison formed by infra-red rays and with the locating of the enemy's batteries by means of flashes.

In the field of tele-mechanics it was my privilege to make tests before a special commission indicating the utility of such apparatus for releasing at a distance a definite mechanical action, by means of a luminous or calorific ray.

For this purpose a cell having a sensitive surface 50 by 60 mm. in extent, was connected with a relay and with a battery of about four volts; the contact of the relay was inserted in a circuit comprising a second battery of cells and an ordinary sounding device. The ensemble was placed in a box which could be readily transported. The cell was illuminated without special precaution by the luminous beam of a small automobile searchlight of about 1,000 candle power. The tests were made at night in June, 1915.

The cell was transported to distances which increased from 0 to 500 m.; by means of a screen the shaft of light could be shut off at will. Up to 500 m., which is not the extreme limit of operation, the cell was definitely influenced and the bell was sounded without trouble. . . .

MILITARY TELEGRAPHY.

The problem of the liaison between a fighting unit and a post of command, for example, by means which the enemy was incapable of detecting, led to interesting researches in military telegraphy. For this purpose I furnished in 1916 a cell having a sensitive surface of 30 by 30 mm., which when placed in the focus of a special parabolic mirror was influenced by the infra-red rays emanating from a transmitting post composed of a calorific source (an oxy-hydrogen flame impinging upon a tablet of a rare earth), a diathermic screen which was opaque to luminous rays and a parabolic mirror, and finally of a mechanical interrupter activating an a-thermic screen provided with a diathermic aperture allowing calorific rays to pass. Since this screen revolves at high speed we obtain a number of interruptions of the calorific bundle of rays corresponding to the number of revolutions of the driving motor. At the receiving post a telephone inserted in a circuit comprising the cell and an accumulator reproduces, in the form of a continuous sound, the intermittent interruptions of the calorific bundle of rays; if by means of a special de-

*Translated for the *Scientific American Monthly* from *Chemie et Industrie* (Paris). Part I appeared in our January issue and Part II in our February issue.

[1]Selenium is very sensitive both to infra-red radiations and to calorific radiations, to such a degree indeed that the mere entrance of an individual into a room causes a sufficient increase of heat to perceptibly diminish the resistance of the cell, as has been demonstrated by Dr. Guilliminot with one of the cells made by us. (*Ann. d'Electrobiologie et de Radiologie*, 1914, No. 1.)

[2]Louis Ancell, Bull. Soc. Chim., l.c.

vice we interrupt the stream of rays in such a manner as to produce Morse signals, the latter are clearly perceived at the receiving post, especially if we have taken pains to insert an amplifier in the circuit of the cell, in place of the telephone.

It will be perceived that since the calorific rays and the signals of this kind cannot be detected by the enemy it is possible to obtain a comparatively practical *liaison* by this process between two posts, either fixed or movable, several hundred meters apart.

LOCATING ENEMY BATTERIES BY FLASHES.

Another military application of selenium is connected with the locating of enemy batteries by the flashes of light from

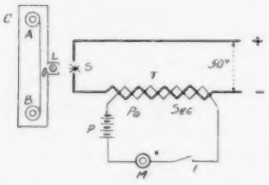


FIG. 1. LAYOUT FOR PHOTOGRAPHING SPEECH

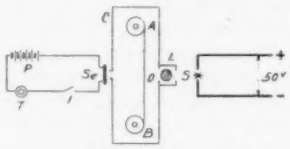


FIG. 2. REPRODUCTION OF SPEECH BY PHOTOGRAPHY

the mouths of big guns. Since the cells are sensitive even to the faintest luminous intensity and since their inertia is practically negligible, it is only necessary to place a cell at each of three different posts located a few kilometers apart, and to connect each cell (all the cells, of course, being influenced by the flashes from the enemy guns) with a suitable graphic recorder provided, as in the apparatus constructed by us for the measurement of inertia, with a time recorder. The instantaneous flash of an isolated gun would influence all three cells at the same moment; at this moment the three recording devices will indicate the variation of resistance of the cell by a corresponding deviation of the recording stylus. A phonographic comparison of the three diagrams thus obtained and a very simple calculation in trigonometry will give the location of the enemy battery. However, because of the highly improved and highly practical modern methods of locating guns by the sound, the method just described has been utilized only experimentally.

SCIENTIFIC APPLICATIONS—PHOTOGRAPHING WORDS.

Undoubtedly one of the most curious scientific applications of selenium is the reproduction of sound by means of photography. To begin with an impression is made upon an ordinary photographic film by means of luminous rays emanating from a *singing arc S* (Fig. 1) passing through a cylindrical lens *L*. The singing arc comprises an arc supplied by a continuous current. Within the circuit of the arc there is inserted the secondary coil of a transformer whose primary coil is connected with a microphone *M* and with a battery *P*. The focus of the lens *L* coincides with the surface of the film which unrolls from *A* to *B* in a dark chamber provided at *O* with a rectangular slit parallel to the lens *L*.

When one talks in front of the microphone the modulations of the voice modify the luminous intensity of the arc; the film which is unrolling with a continuous movement records these variations of luminous intensity in the form of bands which are alternately light and dark.

If now this film be illuminated by an arc such as *S* (Fig. 2), and if the luminous rays, more or less interrupted by the unrolling film, pass through an orifice made in the wall of the dark chamber and fall upon the selenium cell *Se*, then the telephone *T* inserted in the circuit will reproduce in the form of sound (somewhat weakened it is true) the variations of luminous intensity produced by the passage of the film between the arc and the cell. Here we have an original means of preserving a tangible memory of the human voice by means of a photographic phonogram. Singing and other music are produced especially well by this process.

WIRELESS TELEPHONY.

One of the most interesting applications of selenium is wireless telephony by luminous waves, because of the practical results obtained by this in the early years of the present century, when wireless telephony by Hertzian waves was in its early stages and when the new vacuum lamps utilized in the course of the great war were almost unknown.

The principle upon which the majority of the processes of wireless telephony by means of luminous waves and selenium are based, consists in general of influencing at a distance a selenium cell *S* (Fig. 3) placed at the focus of a parabolic mirror *m* and connected with a battery *P* and with a telephone *R* by the luminous rays of a singing arc *A* placed at the focus of a parabolic mirror *m*. When one speaks in front of the microphone the vibrations of the voice produce variations of luminous intensity in the arc *A*; the volume of the flame of the arc varies sufficiently to cause the arc to reproduce the sounds uttered in front of the microphone *M*. Furthermore, the variations of intensity of the luminous bundle of rays are revealed at the receiving post by corresponding variations of intensity in the current traversing the cell and the telephone. The latter reproduces, therefore, the sounds emitted in front of the microphone and transmitted in some sort by means of the light.

TELEVISION.

Both in France and in other countries attempts have long been made by inventors successfully to transmit images to a distance; some of these devices have been based upon the use of selenium. The limits of this article do not permit us to enter into details of these various processes. By way of example we will describe the main features merely of the one invented by Professor Korn in 1907. The principle of this method of transmission is almost the same in the various systems except for variations with regard to the functioning of the different organs.

The image to be transmitted is rolled in the form of a photographic film around the cylinder *C* (Fig. 4) in the interior of which is placed a thick selenium cell *R*, connected with a

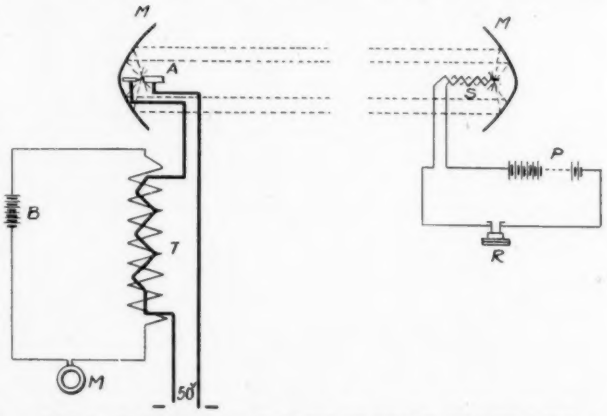


FIG. 3. WIRELESS TELEPHONY BY MEANS OF LUMINOUS WAVES

battery and with the line 1. A lens *L* whose focus coincides with the surface of the film concentrates the rays of the lamp *S* through the film *D* upon the cell *R*; in order to enable a luminous ray to traverse all the elements of the image the cylinder *C* is operated laterally.

At the receiving post a cylinder *p*, which is synchronous with the transmitting cylinder receives a sensitive photographic film. The cylinder *p* is placed in a dark chamber and is illuminated by a high frequency tube *T* supplied by the circuit *HF*; in this circuit there is a movable needle e_1 e_2

whose extremities are just opposite two small spark points. The needle is supported by a galvanometer *G* connected with the line wire and with the cell.

When the needle is displaced under the influence of the variations of the current in the cell, sparks of varying length pass between the spark points and the needle, modifying the luminosity of the tube *T* and correspondingly the photographic impression of the film. After being developed the latter reproduces the image *D* placed at the transmitting post.

An official experiment was made with this interesting device Feb. 1, 1907, upon the premises of the magazine *L'Illustration* over the telephone circuit Paris-Lyons-Paris (1024 km.) in the presence of Ministers Barthou and Simyan, the image transmitted being a portrait of President Fallière.

Among the numerous other inventors who have attempted to accomplish television we may mention MM. Armengaud (1908), Belin, Ruhmer (1909), Rignoux and Fournier (1911). The principle of these various inventions consists in projecting the image to be transmitted upon a frame covered with selenium cells, this image consisting, in general, of sections which are alternately light and dark, like a letter written in white or black. Each of these cells is connected with a galvanometer to whose movable frame is attached a small reflecting mirror at one side, which reflects the light of a lamp upon a screen placed at a given point. The different cells, some of which are illuminated while others are not, therefore throw upon the receiving screen the illuminated or the non-illuminated parts respectively, at the various points which correspond to them by means of reflective rays which are either interrupted or not interrupted by shutters. We thus obtain upon the receiving screen a somewhat blurred projected image.

PHOTOMETRY.

Finally we may mention a last application of selenium which may in some cases be of service in chemical industries—photometry.

In this case those cells which possess an extremely reduced amount of inertia are evidently indicated, and the method can as well be applied to the photometry of certain astronomical phenomena,[3] in particular of eclipses, as to the measurement of the intensity of radiation of an X-ray tube.[4]

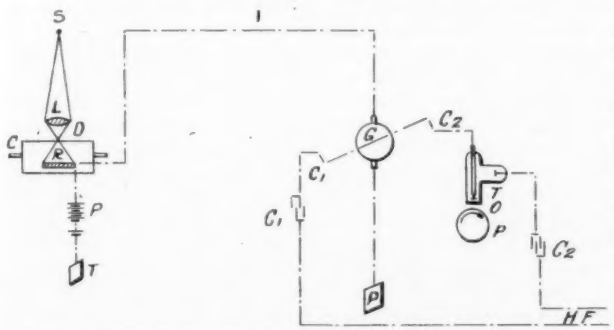


FIG. 4. TRANSMITTING PICTURES BY THE KORN PROCESS

The photometric curve (Fig. 5) which we obtained at the time of the eclipse of the sun, April 17, 1912, is an example of the interesting results obtained with a sensitive cell and with greatly reduced inertia. The cell (34 x 23 mm.) which was arranged vertically was illuminated by the solar rays reflected by the mirrors of a heliostat and connected with a 4-volt accumulator, with a milli-ampere meter and with a photographic recording galvanometer. The record began at 10:45 A. M. and ceased at 2:50 P. M. The intensities of the current in the cell were plotted in ordinates upon the curve by means of a preliminary calibration effected by means of the milli-ampere meter inserted in the circuit. The times plotted in abscissae, were determined by means of hour signals sent out that same day by the radio-telegraphic post of the Eiffel Tower. At the precise moment of an hourly signal a key was pressed manually for a period of five seconds

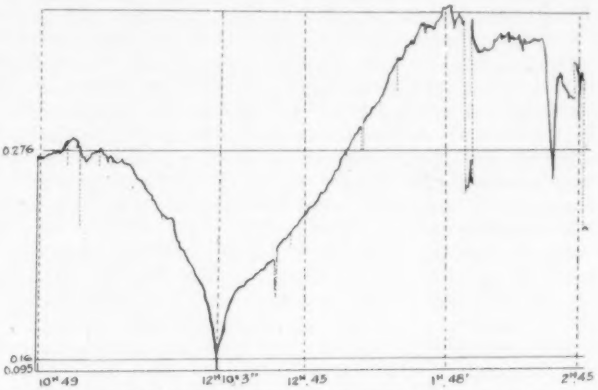


FIG. 5. PHOTOMETRIC CURVE OF THE ECLIPSE OF THE SUN ON APRIL 17, 1912, OBTAINED BY MEANS OF A SELENIUM CELL

closing a circuit comprising an accumulator and a 2-volt lamp attached to the interior of a blackened box containing the galvanometer. This lamp by illuminating a slit made in the frame of the recorder and provided with evenly spaced vertical metal wires interrupting the luminous ray threw a broken straight line upon the sensitive paper. The light intervals upon these straight lines and upon the curves made it possible to graduate the latter in intensities according to the previous calibration mentioned above.

It is evident that at the moment of totality it exhibits a very definite point of retrogression; at this moment (10 min. 6 sec. past 12 M.) the intensity read upon the milli-ampere meter was 0.095 ma.[5] The small oscillations visible upon the curve proceed from the vibration of the mirror of the galvanometer, the latter being due to the tremors of the ground; the more important oscillations proceed from slight imperfections of the mirrors of the heliostat and the sudden drop of the curve due to clouds passing before the sun.

This example is sufficient to show the value of the method whenever we are concerned with measuring or with comparing the variations of intensity of luminous or calorific radiations. The case presents itself in certain reactions which occur in metallurgy and chemical industry; the process is simple and is in general use, since few other substances exhibit so great a sensibility as that of selenium to radiations which are so varied, ranging from the infra-red to the ultra-violet, and including X-rays and radium rays.

THE FUTURE OF SELENIUM AND ITS APPLICATIONS.

While the use of selenium does not appear to be capable of becoming widely extended either in industrial chemistry or in the manufacture of violet colored glass, or in the vulcanization of rubber, its electro-technical applications, on the contrary, appear to be as varied as they are interesting. The various manners of employing selenium which we have just passed briefly in review give but a faint idea of the flexibility with which this metalloid can be employed in the form of cells; and while industry may hope to find in it a valuable aid in the control of the draught of smoke and of the rate of progress of a chemical reaction, we may also be allowed to hope that it will yield to our descendants the possibility of conversation and of vision at a distance.

[3] *Louis Ancel, La Photométrie de l'Eclipse de Soleil du 17 Avril, 1912 à l'Aide du Sélénium et d'un Galvanométre En Aegistreue Photographique.* C.R.Ac.Fr., vol. 155, p. 267, July 21, 1912.

[4] H. Guilleminot. *Sur les Variations de Résistance du Sélénium Exposé aux Rayons X et aux Rayons de Radium.* Ann. d'Electrobiologie et de Radiologie, 1914, No. 1.

[5] By reason of an error made by the engraver the point of retrogression of the curve at the moment of the totality was incorrectly indicated at 10′ and 30″ past 12 M.

Radiation and Chemical Change*

Cause of Reactivity of Different Chemical Substances Toward One Another

By W. C. McC. Lewis

ONE of the most important problems of modern chemical science is that which deals with the origin and cause of the reactivity of different chemical substances towards one another. As an approximate measure of reactivity, regarded as a function of the nature of the material and of the conditions under which it is examined, we may take the rate or *velocity* with which a given molecular species spontaneously decomposes or reacts with another molecular species. The substances which react together are usually called the reactants, the substances which are formed as a result of the reaction being called the resultants.

For the last fifty years the guiding principle which has been applied to this problem of chemical kinetics with the greatest success is that known as *the principle* of active mass or *mass action*, first enunciated by Guldberg and Waage. According to this principle *the reactivity of a substance is measured by its concentration*, the greater the concentration the greater the reactivity. Thus the rate at which a given substance decomposes (let us suppose in the gaseous state), is proportional to its concentration at the moment considered. The velocity or rate is expressed usually as the number of gram-molecules of the substance which disappear per second in one litre of the system, the concentration itself being expressed usually as the number of gram-molecules of the substance per litre. The proportionality factor which connects the rate of the reaction with the concentration of the decomposing substance is called the *velocity constant* of the reaction. As the reaction proceeds its rate falls off owing to the diminution in the concentration of the reacting substance. The velocity constant, on the other hand, retains the same numerical value throughout the entire course of the reaction, and this numerical value may be employed to characterize the process in question.

The principle of mass action has been verified in numerous cases, which, chemically speaking, are of the most diverse character. The principle has been extended and applied, notably in connection with the thermodynamic theory of affinity and its measurement, so that, today, we may say that a very large part of physical chemistry rests upon this concept of mass action.

We must bear in mind, however, that the principle of mass action is a formal and limited statement after all. The general problem, which modern physical chemistry has to solve, is this—what lies at the basis of this formal principle? In attempting to answer this question we are brought immediately face to face with the problem of the inner molecular and atomic mechanism of chemical change. To solve this general problem completely is, at the present time, quite impossible. There are, however, certain aspects of the problem which may be usefully considered and upon which we now possess a certain degree of knowledge. Two important questions present themselves. First, is the concentration of a substance, *per se*, a sufficiently exact and complete mode of representing the chemical reactivity of the substance? Secondly, how are we to account for the well-known and very marked influence of temperature upon the velocity—and therefore upon the velocity constant—of any given reaction?

With regard to the first question, one or two simple considerations will suffice to show us that concentration alone is not an adequate measure of chemical reactivity; many substances will not react together whatsoever values be given to their concentrations. This of course is not to be taken as a criticism of the principle of mass action itself, for all that the principle professes to do is to determine the magnitude of the reaction after it has been ascertained *by experiment* that the substances considered are capable of reacting at all. What is more to our present purpose is the fact that *one and the same substance exhibits a different degree of reactivity according to the nature of its surroundings i. e.*, according to the nature of the medium in which it is dissolved. If one alters the medium one alters the reactivity of the dissolved substance. This is to be exemplified by Menschutkin's work.[1] Menschutkin observed that the series of velocity constants for one and the same reaction follows roughly the values of the dielectric capacities of the various solvents in which the reaction proceeded, although there are several exceptions to the statement which cannot be discussed now. It is evident that this electro-magnetic property, the dielectric capacity of the medium, has something to do with the rate. From these facts we infer that the principle of mass action correctly accounts for the rate of the reaction once it has started, but is unable to account for the influence of different solvents upon one and the same reaction. We arrive therefore at the important general conclusion that *chemical reactivity depends not only upon concentration but also upon the environment in which the reaction proceeds.* Now, how are we to express this dependence upon the environment? To get some idea of this we must return to the second of the two problems which we set before us, namely, that dealing with the influence of temperature upon the rate of reaction.

It has been shown as a result of numerous investigations that the velocity constants of reactions are very sensitive to temperature, a rise of 10 degrees causing a marked increase in the velocity constant. If we are considering ordinary room temperatures we may say that a rise of 10 degrees causes the velocity constant to treble or even quadruple itself. That is, there is an increase of 300% in the velocity for an increase of only 3% in the absolute temperature. Now this very marked increase in the velocity of the reaction cannot be accounted for simply on the ground of an increase in the speed of movement or translation of the molecules, for it can be easily shown that a rise of 10 degrees increases the frequency of collisions between molecules by only about 2 per cent, whereas the increase in reactivity is of the order 300 per cent. It is fairly certain, therefore, that the effect has to do with *the internal energy of the molecules.*

On the basis of the socalled Quantum theory of specific heats it is known that when heat is added to a body the energy distributes itself unequally among the various molecules, so that while some receive no energy at all others receive a quantity which might be called the average amount, and a few molecules receive excessively great amounts of internal energy. It would seem therefore that the influence of temperature upon reaction velocity is to be sought in the existence of a relatively small number of the total molecules present which have received an abnormally large quantity of internal energy. The fact, that many reactions occur with a *finite* and measurable velocity, shows us that *all* the molecules are not in the same chemical state. If they were, the speed of the reaction would either be zero or practically infinite. This consideration also leads us to look for a certain differentiation between the molecules of a substance as regards internal energy content.

A considerable advance in the problem of the relation of the velocity of a reaction to the temperature was made by Arrhenius[2] in 1889, who suggested that the velocity constant was an exponential function of the temperature.

*Republished from *Scientia*.

[1] Menschutkin, *Zeitschr. für physikalische Chemie*, 6, 11 (1890).
[2] Arrhenius, S., *Zeitschr. für physikalische Chemie*, 4, 226 (1889).

The equation of Arrhenius involves an empirical constant quantity denoted by A. The term A is characteristic of a given reaction. If we know by experiment the numerical value of A and the value of the velocity constant at any single temperature we can then easily calculate, with the help of the equation of Arrhenius, the velocity constant at any other temperature. The term A can be shown to be an energy term and is numerically very large.

This expression of Arrhenius has been applied to numerous reactions and has been found to hold with a considerable degree of accuracy. But it must be clearly understood that the expression itself is largely empirical although Arrhenius has attempted to find a theoretical basis for it. The importance of this equation of Arrhenius for our present purpose lies in the fact that there must be some close connection between the mechanism of a chemical reaction and the influence of temperature upon the velocity constant. In short, what we are attempting to do is to visualize some reasonable mechanism for the effect of temperature upon the velocity constant of a given decomposition, and then to transfer the idea to the mechanism of the reaction itself as it proceeds at any given constant temperature.

The most important suggestion yet made in connection with the effect of temperature upon reaction velocity (which finds its formal expression in the equation of Arrhenius), is that of Marcelin[3] (1913), which was rendered more exact later by Rice.[4]

Marcelin and Rice treat the effect of temperature from the standpoint of statistical mechanics. The physical idea underlying it is that a molecule in the mean or average state, that is, a molecule containing the *average* amount of internal energy is chemically *non*-reactive. Since however, the internal energy is distributed unequally over a large number of molecules, it must happen that a small number will receive an abnormally large amount. According to Marcelin, when the internal energy of a molecule reaches or exceeds a certain high value, called the *critical energy*, the molecule is then capable of reacting in a chemical sense. The *additional* energy which a molecule in the mean or average state must receive in order to make it reactive in the above sense is called the *critical increment*. We shall denote this quality by the letter E, it being understood that E is expressed in calories and refers to one gram-molecule as the unit of mass. If there are N actual molecules in one gram-molecule then E/N represents the critical increment per single molecule. In the case of the decomposition of a single molecular species,—the dissociation of gaseous iodine, for example, into its atoms,—the activated molecules do not possess a real existence, for the act of activation, *i. e.*, the act of reaching the critical state is identical with the act of separation of the atoms which may be thus considered as free for the first time. On the other hand the activated molecules of hydrogen iodide gas can exist; when one such molecule collides with another similarly activated they react together giving rise, as is well known, to hydrogen and iodine gases. On the Marcelin-Rice view, as adopted by the writer, the rate of decomposition or dissociation of a gas, *i. e.*, a *uni*molecule reaction, is identical with the number of molecules which attain the critical state per second. On the other hand the rate at which hydrogen iodide decomposes is identical with the number of collisions per second between pairs of activated molecules, for it is known that two molecules are simultaneously concerned in this reaction, *i. e.*, the process is *bi*molecular. In both cases however, it is necessary that a certain increase in the internal energy of the molecular species shall have taken place antecedent to the observed chemical reaction itself.

It is not proposed to enter into the mathematical development of this view of the activation of molecules which has been carried out by Rice on statistical lines. Suffice it to say that, on this basis, we arrive at the conclusion that the velocity constant should be an exponential function of the temperature.

In fact we arrive at an expression which is of exactly the same form as that suggested by Arrhenius and must therefore be in as good agreement with experiment. The considerable advantage is, however, that the physical meaning of E which now replaces A is quite definite, authough, of course, the whole argument is based on a generalized treatment which does not solve the problem of actual molecular structure, beyond the fact that in the process of activation the atomic groupings inside the molecule are pulled apart to a certain distance, thereby loosening the bonds between the atoms and permitting certain lines of force to attach themselves to other neighboring molecules. It should be pointed out that sensibly the same view of the atomic mechanism of chemical activation had already been expressed by Baly,[5] who pursued a totally different line of reasoning, based upon observations of the absorption band spectra (exhibited in the ultra-violet region) by various substances under different conditions. It is highly satisfactory that two distinct lines of thought should have led to the same general conclusion.

We have now, however, to push our inquiry one step further. We have seen that the concept of the activation of a molecule by an increase in its internal energy up to the required limit is sufficient to account for the fact of chemical velocity, and the influence of temperature upon the velocity constant. The question now remains in what manner does the molecule obtain this extra increment of energy? What is the ultimate source of this, and indeed of all, molecular and inter-atomic energy, both kinetic and potential? Whatever hypothesis we may adopt it must be such as to permit us to arrive finally at the Macelin-Rice result, for this, as we have seen, possesses sound experimental verification.

In the writer's opinion, the most plausible hypothesis[6] is, that *radiation*, that is energy of the radiational type, *is the ultimate source of all energy which makes chemical reactivity possible.* In the case of ordinary or thermal reactions, as they are called, that is reactions which proceed at ordinary temperatures, the effective radiation is of the short infra-red type. Such radiation is necessarily present throughout any material system in virtue of the temperature of the system. (It is only at absolute zero that we can conceive of radiation as being absent). In the case of reactions, which proceed measurably at high temperatures only, the effective radiation belongs to the shorter wavelength region, namely the visible or ultra-violet part of the spectrum.

The idea that radiation of all wavelengths interpenetrates matter is of course not new. The whole physics of radiation depends upon that. What is particularly important to observe in the present instance is that the radiation, to which is ascribed this fundamental rôle as the *fons et origo* of molecular energy and therefore of chemical reactivity, is essentially temperature radiation. That is, the temperature of the radiation is the same as that of the matter which it interpenetrates. In fact, the temperature of the substance is directly due to the presence of radiation which is being continually absorbed and emitted by the molecules of the material. This postulate, that the radiation which brings about chemical change is at the same temperature as the matter itself, means that we are considering a very different state of affairs from those to which we give the name photochemical reactions. In the latter a source of radiation, usually of the visible or ultra-violet type, external to the material system, emits radiation which is absorbed by the system, thereby bringing about chemical change. Such effects, due to short waves, have long been familiar. In photochemical arrange-

[3]Marcelin, R., *Comptes Rendus*, 157, 1419 (1913); *ib.*, 158, 116, 407 (1914); *Annales de Physique*, 3, 120 (1915).

[4]Rice, J., *British Assoc. Report*, p. 397 (1915).

[5]Baly, E. C. C., *Journ. Chemical Soc.* (London), 101, 1469 (1912); *Astro-physical Journ.*, 42, 1 (1915).

[6]Lewis, W. C., McC., *Journ. Chemical Soc.* (London), 105, 2330 (1914); *ib.*, 109, 796 (1916); *ib.*, 111, 457, 1086 (1917); *ib.*, 113, 471 (1918).

ments, however, the temperature of the radiation is very hign, while the temperature of the material upon which it acts is low. In the case which we are considering, on the other hand, the temperature of the radiation and of the matter is the same.

Having postulated the identity of temperature for the matter and the radiation we are at once justified in applying Planck's Quantum Theory of radiation which deals with such conditions. It is impossible to enter into any of the details of this modern theory of radiation. Suffice it to say that, according to the Quantum Theory, radiation consists of small units of radiant energy, called quanta, and that radiation may be absorbed or emitted by molecules of matter one quantum at a time. This, at any rate, is the very simplest statement that can be made to convey in a "rough and ready" way the concept of quanta. These small units or quanta are each proportional to the vibration frequency of the radiation which they represent.

Briefly, the radiation hypothesis of chemical reactivity states that *the rate at which a substance decomposes or interacts depends not only upon its concentration, but simultaneously upon the density of that type of radiation which the substance can absorb*, for of course, it is only the absorbable radiation which can be effective. This statement is virtually a new or modified principle of mass action. It does all that the older principle is capable of doing, and at the same time is capable of taking account, at any rate to a large extent, of the effect of temperature and the influence of environment upon the velocity constant and therefore upon the reactivity of the molecular species considered.

Naturally the idea that radiation could bring about ordinary or thermal chemical change is not new. It must have occurred to almost anyone who was familiar with the facts of photochemistry. Photochemistry, in fact, is a special case of general radiation chemistry. The important thing is, however, the introduction of the Quantum Theory which allows us to express the radiation hypothesis of chemical reactivity in a more or less quantitative form. Without going into details the radiation hypothesis leads to the conclusion that the velocity constant of any ordinary reaction should be an exponential function of the temperature in complete agreement with the conclusions of Marcelin-Rice and Arrhenius. In place of the term E in the Marcelin-Rice expression, we now find a term denoting the total number of quanta absorbable by one grammolecule, which leads at once to the conclusion that the critical increment of a single molecule is just one quantum of the absorbable type of radiation. This is identical with the well-known law of the "Photochemical Equivalent" first enunciated by Einstein.[7] Einstein's law takes on therefore a new and wider significance. If, therefore, we know the type of radiation (*i. e.*, the wavelength or frequency), which the substance is capable of absorbing (in the proper part of the spectrum) we can calculate the effect of temperature upon the velocity constant. Conversely, from the observed effect of temperature upon the velocity constant, we can calculate the wavelength of the radiation which the substance is capable of absorbing and by means of which it is able to exhibit chemical reactivity. It has been found by the writer that such calculated wavelengths agree well with the known positions of absorption bands possessed by substances. At the present time the chief difficulty is the lack of spectroscopic data, as the velocities of reactions have been measured in numerous cases in which knowledge of the corresponding absorption spectra is entirely wanting. So far as the data are available, however, the radiation hypothesis has been substantiated. Further, from such data it has been shown that the *heat* of the reaction[8] can be calculated, and this conclusion has likewise received a certain amount of experimental verification.

Again, the radiation hypothesis requires that the velocity constant of a reaction should depend upon the cube of the *refractive index* of the system for the wavelength absorbed, *i. e.* for the wavelength which is causing the chemical change. On the classical electromagnetic theory of radiation it is well known that there is a very close connection between the refractive index and the dielectric capacity. Hence on the radiation hypothesis we would expect a close relation between the velocity constant of a reaction and the dielectric capacity of the system in which the reaction proceeds. It has already been pointed out that the results obtained by Menschutkin and others entirely support such a conclusion. At the present stage this and other conclusions have a qualitative rather than a quantitative basis, and there are a number of *apparent* exceptions to the rule. The application of the Quantum Theory of radiation to chemical reactivity is very recent, and especially under present conditions it is impossible to carry on the necessary research work which the hypothesis suggests. The field, however, is very promising and the results so far obtained are sufficient to give very strong *prima facie* grounds for the general truth and applicability of the concept that the radiation, necessarily present in material systems (in virtue of their temperature) is the fundamental source of chemical change of all kinds.

[7] Einstein, A., *Annalen der Physik*, iv., 37, 832 (1912).
[8] Lewis *loc. cit.*

SODIUM FLUORIDE AS A WOOD PRESERVATIVE

TESTS made years ago at the Forest Products Laboratory indicated that sodium fluoride might be successfully used as a wood preservative, because it had high toxicity, was not injurious to metal, and was convenient to handle. Laboratory tests alone, however, are never sufficient to establish the value of any material as a wood preservative; actual service tests, even though they require years to complete, are also needed.

In order to obtain comparative durability records, the laboratory in 1914 placed sap-pine ties treated with sodium fluoride, together with ties treated with zinc chloride and creosote, in one of the mines at Birmingham, Alabama. Similar service tests were also started at this time on red oak ties placed in the tracks of the Baltimore and Ohio Railway Company.

After five years of service the mine ties which were treated with sodium fluoride have been found in as good condition as those treated with zinc chloride, both showing very little deterioration. The creosoted mine ties apparently were in still better condition, while the untreated ones were in various advanced stages of decay. The red oak railway ties treated with sodium fluoride were practically all sound, as were those treated with zinc chloride, whereas a large percentage of the untreated oak ties had been removed.

Both of these tests, as well as others started later, must continue for a number of years yet before the relative value of the sodium-fluoride treatment for ties and timbers is definitely known.

NEW TYPE OF CLAY-DIGGING MACHINE.

A MACHINE has been designed to replace the usual method of extracting clay (viz., excavators, breakers, blasting), especially the rich plastic clay used in the refractories industry. The machine consists essentially of a rack 8 to 10 m. long running between guide-rolls and resting on a scaffolding traveling along the upper edge of the clay being worked. Underneath the rack is a box-shaped cutting tool of rectangular section. The strip of clay extracted by this tool is cut up into slabs by a second knife acting automatically. The whole is driven by a 4-10 h.p. electric motor or gasolene engine, one man being required for operating. Output: 50 to 200 cbm. clay in 10 hours.—*Technische Zeitschriftenschau*, Nov. 15, 1919. Abstracted through *The Technical Review*.

Testing Seeds with a Thermometer

Infection or Debility Shown by the Temperature Developed

By George J. Peirce, Professor of Plant Physiology, Stanford University

HOW can the farmer test the quality of his seed-grain, corn and alfalfa? How can one find out quickly and cheaply the quality of the garden-seed offered in gay envelopes by grocer and druggist? How can the qualities of grain cargoes coming into the great ports be ascertained without great expenditure of time and money?

These are questions not of idle curiosity merely. They are practical questions which have been answered in certain instances, and the method is of wider usefulness.

When Sir James Dewar, one of Faraday's successors at the Royal Institution, in London, was liquifying air and solidifying carbon-dioxide and various other gases, he required containers which should not only mechanically hold his products but should at the same time insulate them. He made double-walled flasks, bottles, and cylinders of glass, electroplating the inner and outer walls of the outer and inner bottles, and exhausting the air between them. These double-walled vessels are known in chemical and other laboratories; but they are known generally as thermos bottles, or "icy-hots." A thermos bottle, with its shiny, nickel-plated metallic case, is essentially a silver-plated vacuum. The principles involved in the thermos bottle or Dewar flasks are simply these: that heat-waves do not traverse a vacuum, though they will pass through air, water, etc.; and that they, like the waves of light and sound, may be reflected by mirrors. The silver-plating furnishes the mirror-like surface, and greatly increases the efficiency of the thermos or Dewar bottle as an insulator.

In many laboratories of botany, all over the world, students have been shown that germinating peas, opening calla-blooms, and various other living parts of plants, liberate heat. The containers and insulators formerly used were ordinary vessels of glass, wrapped in cow-hair felt, absorbent cotton, etc., all of which are relatively poor insulators. Of late years, however, Dewar vessels and thermos "refills" have replaced the cumbersome and unsatisfactory wadded vessels, and instead of the low and misleading temperatures formerly taken, we now know that peas have their comparatively high and "normal" temperatures just as human beings, cows, horses, and other animals have. The "normal" temperature of an adult person is 98.6° Fahrenheit. If a person's temperature, as taken in the mouth, under the tongue, is over 98.6°, the physician recognizes fever and looks for the place and kind of infection; or if it is under, then he seeks for the reason for the debility thus indicated. By putting a known weight of good peas with an equal quantity of cooled boiled water into a Dewar flask or thermos bottle and keeping this loosely corked or cotton-plugged for two days, one should find the thermometer indicating a temperature inside the flask considerably higher than that of the room. Thus, in a certain experiment 2¾ ounces of American Wonder extra early garden peas were nearly 20° warmer at the end of two days than when they were put into the insulator. But among these peas four were found that were decaying. Examination showed them to be weevily. The weevil holes were infected and this infection caused the abnormally high temperature. On the other hand, another experiment with an equal quantity of peas four years old showed a decidedly lower temperature in the same length of time. In other words, the vigor and soundness of these two lots of peas was plainly indicated, in 48 hours, by the temperatures developing in these test lots in Dewar or thermos bottles. The temperature of the fresh peas was above normal because they were weevily and fungus or bacteria infected; and the temperature of the old peas was low because they were weak from old age. But in a bottle of four-year-old and carefully sterilized hemp seed no temperature would develop because hemp seed loses its germinating power in about two years. Clover seed yields a normal or sub-normal temperature according to its freshness; but if it is contaminated or infected seed, it will have "fever."

Thus the vitality, germinating and growing power, cleanness, and soundness of seeds can be determined, according to the kind of seed, by the very simple test indicated in a considerably shorter time and with much less trouble than would be required to make any other germination test in soil or what not. But just as there are warm and cold-blooded animals, so there are quick sprouting and slow sprouting seeds. But if one knows the normal behavior of seeds, one can tell at once, by the abnormal temperature developing in a Dewar or thermos bottle containing them, whether a given lot is good or bad. The wisdom of buying or sowing such seed is indicated very promptly and definitely.

These thermos bottle tests are not limited in applicability to seeds, for some of the qualities of milling grains, hay, etc., can be ascertained swiftly and accurately in this way. If a given lot of wheat intended for the flouring mills is found to contain insects, it can be fumigated and thus relieved of these pests. But if it contain fungus or bacteria besides the insects, fumigation will not sterilize the grain. The quality of the flour, and its value in bread-making, depend in part on the grain being clean, that is, free from pollution of any sort. Infected flour will not make bread which will be satisfactory in its rising power, texture and flavor. Furthermore, imported grain may bring foreign grain and other diseases into the country, and the danger of so doing can be ascertained by diagnosis based on temperature tests.

Some of these possibilities have been realized in practice,[1] but the use of the Dewar or thermos bottle tests of grain, seeds, etc., can be greatly extended from a laboratory of "pure science," where, like the thermos bottle, it started, to commercial uses.

SPEED OF SOUND-PULSES IN PIPES.

WRITING in the *Physical Review* for August, 1919, A. L. Foley describes experiments to determine the speed of sound in pipes. The sound was measured by a photographic method; short tubes were used, placed near a spark source. An instantaneous photograph was obtained of a sound-pulse, part of which had come through a tube, while another part had come through free air. In this way the effect of short tubes of various sizes was determined when their near ends were from 1 to 5 cm. from the spark. Two photographs are reproduced which show that in some cases the pulse may travel faster through a short tube than in free air, and faster through the smaller of two tubes than through the larger. The speed through a tube was found to depend chiefly on the intensity of the pulse as it entered the tube, and this was true even when the motion of the air as a body was prevented by a thin collodion membrane stretched across one end of the tube. The mean speed was less the longer the tube. The paper includes an historical survey of the work done on the speed of sound in pipes, with a two-page table of results obtained.—From *Science Abstracts*.

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[1]Peirce, G. J. A new respiration calorimeter. *Botanical Gazette*, vol. 46, 1908. The liberation of heat in respiration, *Botanical Gazette*, vol. 53, 1912. A study of the germinating power of seeds, *Botanical Gazette*, vol. 58, 1914.

The Capillary Circulation*

How Are These Blood Vessels Dilated and Contracted?

By W. M. Bayliss, F.R.S., M.A., D.Sc.

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ALTHOUGH the part played by the small arteries, arterioles as they are usually called, in regulating the height of the blood-pressure and the supply of blood to the tissues of the various organs is fairly well known, that of the capillaries and the veins remains more obscure. The fact that the arterioles possess a muscular coat of relatively considerable thickness, while the capillaries consist merely of a single layer of epithelial cells, renders the mechanism of contraction and dilatation of the former easy to realize. Their nervous supply has also been worked out in some detail, and the facts of their active changes in calibre under the stimulation of various nerves and under the influence of different kinds of drugs and other chemical substances are generally admitted.

The veins also possess a muscular coat, but of much less thickness than that of the arterioles. Some evidence exists that they are capable of changes in calibre; but the object of the present article is to consider rather the facts that have come to light in recent times with regard to the properties of the capillaries, together with the consequences, theoretical and practical, that follow them.

The difficulties in supposing that the capillary blood-vessels have the power of altering their calibre independently of the pressure of the blood entering them appear to be largely due to the absence of a muscular coat. On the other hand, a fairly copious supply of nerve fibres to them has been described, and we know that cells other than muscle cells can change their form when stimulated. The pigment cells of the skin in fish and frogs may be mentioned, and the spherical forms assumed by the amoeba and the leucocytes are familiar. Thus the absence of a muscular coat in the case of the capillaries does not warrant a denial of the possibility of active changes in calibre in the latter.

If the reader will examine, under a low power of the microscope, the circulation in the web of the frog's foot—and there is probably no more interesting thing in the whole of physiology—he will notice how great is the volume of the capillaries compared with that of the veins and arteries. He will see that the rate of the flow of blood in the arterioles is, accordingly, very much greater than that in the capillaries; and, remembering that the friction is proportional to the velocity, he will realize the great effect that changes in diameter of the arterioles have on the pressure on the arterial side of the system. But he will also appreciate how large a volume of blood can be contained in the capillary region, and that a comparatively small increase in the diameter of the capillaries, if present in a large part of the body, will suck up, as it were, a great proportion of the blood present in the circulation. The importance of this fact is that the amount flowing into the heart from the great veins will be less, and therefore also that driven out into the arteries on contraction of the ventricles. Hence there will be a fall in blood-pressure and deficient supply to the tissues generally. Thus, although the capillaries may be wider, the current through them will be diminished by the decrease in driving pressure, in addition to the lower rate of flow involved in their increased width. Under ordinary circumstances, as described by Lister and by Langley, some of the capillaries are more or less empty of blood, and become filled only when dilatation occurs. This is an additional way in which blood is accumulated in capillary networks. This fact has recently been further investigated by Krogh, who shows that, in resting muscle, only a small number of the capillaries are filled with blood. In activity, a greater or less proportion of the remainder becomes dilated and conveys a current of blood. According to his experiments, it requires a fairly high pressure to open up the collapsed capillaries; so that, if an increased supply of blood is needed by an organ, it is necessary that an active dilatation of the capillaries should occur, as well as one of the arterioles. It appears that, if the latter alone were to take place, a comparatively small increase in blood-supply would be provided. If the capillaries alone dilate, there is no increase in total supply, or very little, and the blood which continues to flow will be greatly reduced in rate with a tendency to stagnation, with rapid loss of its oxygen. This condition will be exaggerated if the arterioles simultaneously constrict, as happens under the action of histamine.

That the capillaries are not merely passively distended or depleted according to the diameter of the arterioles supplying them is indicated by the common experience of two different effects of external cold on the skin. The color of the skin in white races is almost entirely due to the blood in the capillaries. When the blood supply is cut off, the skin becomes white and cold. This may sometimes happen as the result of the constricting effect of cold on the arterioles; but there are also two familiar states produced by cold which are associated with increased depth of color, and therefore with a greater content in blood. In one of these, the skin is red and warm; in the other, on the contrary, it is blue and cold. It is clear that the warmth in the former cases must be due to an increase in the current of warm blood flowing through the capillaries, and this can only be brought about by dilatation of the arterioles and capillaries. The capillaries are thus filled with a rapidly renewed current of fresh warm blood. In this way, the skin is protected from the deleterious effects of cold. A compromise must be effected between the increased loss of heat from the body and the protection of the skin. It will be remembered that one of the means of getting rid of excessive heat is by dilatation of the vessels in the skin. What is the state of affairs when the skin is blue? Bearing in mind the fact that the color of the blood in the veins appears to be blue when looked at through the skin, we realize that this is the color assumed when oxygen has been lost. The blue color of the blood in the capillaries must be due, then, to its having lost more oxygen than it does when the skin is red. Although the capillaries are dilated, the current through them must be decreased, and this state can only be explained by an expansion of the capillaries independent of that of the arterioles, which are probably constricted. The coldness of the skin is readily explained on the basis of the slow circulation through it. An exaggeration of this blue state of the skin may be observed in certain pathological conditions, and appears to be easily brought about by exposure to cold in such cases.

With regard to more definite experimental evidence of active change in the capillaries, we may note the difficulty of excluding passive effects due to changes in the arterioles. A dilatation in these vessels would raise the pressure at the place where they become capillaries, and naturally distend them to some extent. Lister in 1858 described dilatation of the capillaries in the frog's web under the action of chloroform and other agents. Roy and Graham Brown in 1880 confirmed this observation, and believed that they had excluded the effect of the simultaneous dilatation of arterioles by the fact that if reflex stopping of the heart was brought about, so that the arterial pressure fell to zero, the dilated capillaries did not empty.

*From *Science Progress.*

This, however, is not completely convincing, because the elastic reaction of the capillaries might not be sufficient to empty them after they had been stretched. If the passive stretching had caused an elastic reaction, it is difficult to see why the capillaries did not empty themselves back into the arterioles where the pressure was zero. Better evidence of independent action on the part of the capillaries is afforded by the observation of these investigators that the diameter of different capillaries is not in direct proportion to the arterial pressure. Two capillaries lying side by side may require very different external pressure to obliberate them, and, after a pause, that one which previously collapsed under the lower pressure may now require the higher one.

In 1893, Worm-Müller had shown that large quantities of blood could be injected into dogs without much rise of blood-pressure. The blood remained in the circulation, and post-mortem observations did not reveal a distension of the arteries and veins of sufficient degree to accommodate it. The conclusion was drawn that it was accumulated in the capillaries of the body generally. The adjustment is doubtless brought about by a nervous reflex. It may be that a sufficient explanation lies in dilatation of the arterioles and the resulting passive distension of the capillaries. If this be not accepted, and Krogh's results cast doubt on the acceptability of the explanation, we must assume a direct nervous control of the capillaries by vaso-dilator nerves.

Severini described experiments on the empty capillaries in excised tissues in which oxygen caused narrowing; carbon dioxide widening; but Roy and Graham Brown failed to confirm the observations.

Other observations on capillary dilatation might be quoted but it will be seen that, so far, satisfactory experimental evidence of an independent activity on the part of the capillaries is wanting. This was not afforded until the experiments of Dale and Richards in 1918. Dale and Laidlaw in 1910 were struck by the puzzling action on the blood-pressure of a base, histamine, obtained by removal of carbon dioxide from the amino-acid, histidine, a constituent of most proteins. In the dog, cat and monkey, a marked fall of blood-pressure is produced by very small doses. Now, in the case of certain other drugs having this effect, depression of the heart being excluded, it was known that dilatation of the arterioles was produced, and the explanation of the fall of blood-pressure was easily explained by decrease of peripheral resistance. But tests of the action of histamine on various kinds of smooth muscle, including that of the arteries, showed that it caused *contraction*, and therefore narrowing of the arterioles, an effect which by itself alone would produce *rise* of blood-pressure. By a number of ingenious experiments, the details of which cannot be given here, Dale and Richards showed that histamine causes a widespread dilatation of the capillaries, independent of its effect on the arterioles, which are constructed. It is evident, therefore, that the capillary effect is great enough to overpower that of the arterioles. How is the fall of blood-pressure produced? It seems improbable that a dilatation in such a wide bed as the capillary district, even in normal conditions, should have any marked effect in decreasing the peripheral resistance, especially when the arterial constriction has reduced the blood flow to a low degree of magnitude. The result must be due to removal of blood from actual circulation, an interpretation confirmed by the examination of the heart, which is seen to be empty of blood. In fact, the blood, soaked up by the capillaries as by a sponge, takes no mare part in the general supply of the organs with fresh oxygenated blood than if lost by hemorrhage. In this work, the fall of blood-pressure caused by very small doses of adrenaline in certain conditions was shown to be due to its dilator action on the capillaries.

The practical interest of these experiments lies in the fact that histamine is one representative of a group of substances obtained by disintegration of the protein molecule. In the state of "shock" brought on by extensive injury to tissues, especially top muscle, whether by shell wounds or by surgical operations, observations made at the casualty clearing stations in the late war showed that a state of the circulation similar to that produced by histamine was present. The obvious connection between severe shock and massive injury suggested experimental test. Col. Cannon, of Harvard University, and the present writer found that injury of the thigh muscles in anaesthetized cats and dogs brought on a condition like that of wound shock, and we were able to show that it was not due to irritation of nerves, but to the passage into the blood of some chemical product of the injured tissue. The fact that the state, whether accompanied by hemorrhage or not, owes its dangerous character to the want of blood in circulation, pointed to the treatment which alone was found successful—namely, the filling up of the circulation by transfusion of blood or of some appropriate artificial solution, such as gum arabic in saline.

In regard to the nervous supply of the capillaries, some recent observations by Krogh are of importance. He shows that it is possible, by touching with a glass needle over the situation of a closed capillary in the frog's tongue, to make this vessel dilate, and that the extent to which the dilatation spreads depends on the strength of the stimulus. A similar local effect can be obtained on an arteriole. Degeneration of the nerves to the tongue or the application of cocaine very nearly abolishes the effect, and what remains is sharply localized to the point stimulated. The conclusion is drawn that the spreading of the effect is due to an axon-reflex in sensory fibres, analogous to that suggested by myself (1901, p. 196) for the case of the vaso-dilatation produced by stimulation of the peripheral ends of sensory nerve fibres.

There remains for brief discussion another aspect of the capillary circulation which has important physiological and pathological relations. In the shock produced by histamine, and also in that of wounds in man, it was found that not only was the blood in effective circulation diminished, but what was in circulation had become more or less concentrated by loss of plasma. To understand the cause of this phenomenon, we must consider the evidence as to the permeability of the capillary wall. It is a familiar fact that, when blood is lost, fluid is taken up from that in tissue spaces in order to restore the volume of the blood as far as possible. What is the nature of this fluid? It was shown by Scott that, although the lymph outside the blood-vessels contains proteins, that which enters the blood is devoid of them, consisting only of a solution of the salts and diffusible substances of small molecular size, such as glucose and amino-acids. In other words, the normal capillary wall is impermeable to proteins. If, then the proteins of the blood possess an osmotic pressure, this will be manifest in a tendency to absorb water from the outside. Starling showed that they have such an osmotic pressure, and that it reaches the value of about 35 mm. of mercury. This may be regarded as the force tending to draw water into the blood. But on the arterial side of the circulation, the pressure inside the blood-vessels is about 150 mm. of mercury. This is opposed to the osmotic pressure, and the excess pressure causes the filtration of fluid (=lymph) outwards. Following the blood-pressure as it falls in its course from the arterioles to the capillaries, we find that the pressure inside the latter only amounts to some 10 mm. of mercury. This is less than the osmotic pressure of the proteins, and water is absorbed from the outside. The two processes, however, do not completely compensate one another, and a certain quantity of the lymph is drained off by the lymphatic vessels, being ultimately returned to the blood by the thoracic duct. When we inject into the veins a solution containing salts or glucose only, we decrease the osmotic pressure of the proteins by dilution, more pressure is available for filtration, while the place where reabsorption begins is pushed farther towards the veins, so that a diminished area is in activity. The result is that the fluid injected leaves the circulation rapidly, and the blood returns to its diminished

volume. This agrees with clinical experience. If, however, we add to our injection fluid a colloid possessing an osmotic pressure of the correct value, there is no tendency to loss by increased filtration, and if the permeability of the capillaries is normal the increased blood volume is permanent. The present writer has shown that the addition of 6 or 7 per cent. of gum arabic to the 0.9 per cent. sodium chloride serves this purpose, and such a solution was in extensive use during the later period of the war.

Incidentally, it may be remarked that the filtration of protein-free liquid from the blood-vessels owing to the pressure therein is the view most generally accepted as the first stage of the production of urine.

But there is another way in which increased exudation from capillaries may be brought about. Suppose that the walls become permeable, not only to salts, but also to colloids. There is then no osmotic force to oppose filtration, because the osmotic pressure of the proteins cannot be effective. Now, such an effect is produced by histamine and other products of tissue destruction. If it has reached a high value by prolonged action of the toxic substance, it cannot be restored to normal. Accordingly, in late and severe stages of wound shock, neither blood nor intravenous gum-saline is effective. The liquid escapes from the blood-vessels in a comparatively short time and the blood-pressure fails to its former low level. The occurrence of this condition is shown by the coincidence of a low blood-pressure with a high haemoglobin content of the blood, indicating loss of fluid, whereas normally the low pressure would be associated with dilution. This latter was, in fact, recognized as a favorable sign. If the change in permeability has not become too great, the introduction of blood or gum-saline may restore the normal state.[1]

A similar action to that of histamine on the permeability of the capillary appears to be exerted by prolonged deficiency of blood-supply, probably owing to want of oxygen. The low pressure of shock in itself exaggerates the direct effect of the tissue toxins.

In certain regions of the body, such as the liver, and to some extent, the intestines, the capillaries are normally more permeable to proteins than in other regions, and lymph is accordingly more abundantly formed in such regions. It also contains a certain amount of protein. But, of course, the pressure in the portal vein is much lower than that in the arteries, and the lymph produced also ultimately finds its way back into the blood.

ANATOMICAL MODIFICATION OF ROOTS BY MECHANICAL ACTION.

THE well known naturalist, Mme. E. Bloch,[2] recently presented before the French Academy the results of her experiments concerning external compression of the stalks and roots of various plants. The work was done with the object of reproducing by experiments certain dissymetries of structure which had been observed upon plants which have made their way through stony ground or through the fissures of rocks. It was the investigator's purpose also to study those factors which affect roots or stalks when they develop in various milieu (air, earth, water), and present for this reason those various anatomical differences which were first pointed out by Constantin.[3]

One of the first things observed was that plants having compressed roots and rhizomes—which were collected in stony territory—had flowered and fruited in a perfectly normal manner. It was noted secondly that all plants which had been developed from seeds and later subjected to experimental compression had likewise both bloomed and borne fruit normally.

It is evident, therefore, that the compression which produces very important local modifications has no influence upon the general development of the plant. This result is all the more remarkable since certain ones of the specimens when subjected to compression exhibited very surprising local deformations: thus a root of the *Raphanus raphanistrum*, whose average diameter was 10 mm. is reduced to 2 mm. along a length of 20 mm. by the action of an external tube of glass, and this is by no means an isolated example.

From the anatomical point of view some of the results obtained are as follows: the surface of the bark has a structure which differs greatly according to whether it develops in contact with the glass or in contact with the earth. In the first case, we observe an epidermis having regular iso-diametric cells slightly cutinized and forming only a single layer while a root growing in earth exhibits subero-phellodermic formations with layers of cork arranged in more or less irregularly developed rows. These experimental results may be compared with the phenomena observed in nature in the case of the ivy, for example. The climbing stalk of ivy attached to a support by its "suckers" possesses suber-phellodermic formations in contact with the support, but a simple epidermis upon the side exposed to the air.

Another general modification in compressed specimens is the total or nearly total suppression of the pith, often accompanied by an abundant lignification of the medullary rays. Among those species which normally possess fibres, imprisonment in glass tubes or plates prevents the development of this tissue, no trace of which remains. On the other hand plants having internal fiber continue to differentiate the tissue in the compressed specimens.

Certain general conclusions may be drawn from the ensemble of the results obtained: certain tissues vary with the mechanical conditions in the surrounding medium (such as the nature of medium, external compression); we may call these tissues of adoption. As we have seen these are either tissues of contraction like the epidermis, tissues of support like the fibers and the medullary parenchyma, or else tissues of reserve like the pith.

The other tissues, on the contrary, which may be called *functional* tissues continue to develop in an almost normal manner in almost all cases. Fibers of the wood may be fewer and narrower than in the contrary specimens but they continue to exist and are not modified except in the ensemble. The same thing is true of the liber; thus the internal liber may continue to exist even when the pith which it ordinarily envelops has disappeared.

To sum the matter up, it is possible to reproduce by experiment not only the dissymmetrical structures observed in certain plants, but also the anatomical modifications which result in certain cases from the influence of the milieu. In this manner we may attempt to find the principle by which these phenomena may be explained.

SOYBEAN MEAL FOR CHICKS.

EXPERIMENTS conducted at the Purdue University Agricultural Experiment Station on the relative value of meat scraps and soybean meal as a supplement to corn for growing chicks showed that the former were somewhat inferior to the latter. The best growth came from an addition of 10 parts of protein from soybean meal. The next best gain came from 10, 15 and 20 parts of protein from the combination of soybean meal and meat scraps.—Abstracted from the *Journal of Agricultural Research*, Jan. 2, 1920.

[1] N. M. KEITH, Blood Volume in Wound Shock, *Special Report, No. 26, Med. Res. Committee*, 1919, 36.

[2] Mme. E. Bloch, Concerning the Modifications produced in the Structure of Roots and Stalks by External Compression (in French). C.R.Ac. Fr., vol. 158, 1914, page 1701.

[3] J. Constantin. Influence of the Milieu upon the Root (in French). Ann. d. Sc. Nat. 7th Series, vol. I, 1885; Comparative Study of the Aerial and Subterranean Stalks of the Dicotyledons (in French). Ann. d. Nat., 6th Series, vol. 16, 1883.

Hypersensitizing Commercial Panchromatic Plates*

Effect of Bathing Plates in Alcohol and Ammonia

By Samuel M. Burka, Ph.D.

ORDINARY dry plates, which owe their sensitivity to the silver halides alone, are sensitive only to the violet and blue regions of the spectrum. If, however, a suitable dyestuff be added, the emulsion becomes sensitive to other regions, the particular region depending on the dye used. Thus erythrosin sensitizes to the green and greenish yellow, pinaverdol to the green and yellow, pinacyanol to the orange and red and dicyanin to the extreme red and infra-red.

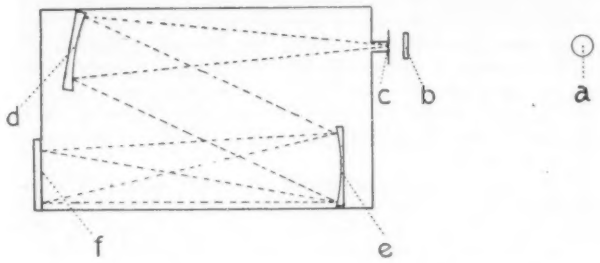


FIG. 1. APPARATUS USED IN THE SPECTOGRAPHIC METHOD OF SENSITOMETRY

a, lamp source; *b*, yellow glass; *c*, slit; *d*, concave mirror; *e*, diffraction grating; *f*, plate to be tested.

The dyestuff is applied to the halides in one of two ways. In the commercial orthochromatic (sensitive to green and yellow) and panchromatic (sensitive to all colors) plates, the dyes are incorporated in the emulsion and the mixture flowed over the glass plate. The second method consists of bathing an ordinary blue-sensitive plate in a dilute solution of the dye and allowing the plate to dry.[1]

The bathed plates are in general faster than the commercial plates[2] and, of course, have the advantage that the plates can be sensitized for any desired region. Certain dyes, moreover (dicyanin, for example), cannot be successfully incorporated in the emulsion. The bathed plates, however, if not used soon after bathing, or if kept at a high temperature, are, in the case of most dyes, more susceptible to chemical fog. Dicyanin and pinacyanol bathed plates when prepared so as to produce the greatest sensitivity are useless after three or four days.

It has long been known that, though at the expense of keeping qualities and freedom from chemical fog, the speed of bathed plates can be increased by the addition of ammonia to the dye-bath. Since this increase is quite marked in the case of some dyes, it was hoped that in this way commercial plates could have their speed increased, and, at the suggestion of Dr. P. W. Merrill, a study was made at the Bureau of Standards of the influence of ammonia on commercial orthochromatic and panchromatic plates.

SENSITOMETRY.

Three methods of sensitometry were used: first, the three-color screen method; second, the spectograph method; and third, the Hurter and Driffield method.

The first method, based on Abney's method,[3] which, however, was used only as a qualitative method at first consists of exposing the plates to a constant light source (usually a nitrogen-filled tungsten lamp corrected by color screens so as to have an energy distribution similar to daylight) behind a so-called trichromatic sensitometer plate. This plate is a neutral screen having four strips of squares of increasing density, each square having twice the density of the preceding. One of these strips is left white, while on the others are placed a red, a green, and a blue filter intended to be of the same luminosity and mutually exclusive. The plates to be tested are thus exposed to varying intensities of white, red, green and blue light.

The second method avoids the difficulty of obtaining filters transmitting pure spectral colors, by exposing the plate in a spectograph.

The apparatus (Fig. 1) consists of a concave grating of 50 cm. radius with 20,000 lines per inch, mounted in parallel light with a 100-watt "daylight" tungsten lamp on 110-volt A. C. circuit as a source. For use with color sensitive plates a piece of yellow glass (7 mm. thick, Corning G 351 CE) barely transmitting the hydrogen blue line with wave-length 4861A was placed in front of the slit to cut out the second order blue. The region photographed was from about 4800A to the limit of sensitivity of the plate. A pair of cross-hairs just in front of the plate at the position of the red line of hydrogen (wave-length 6563A) and of the blue line (4861A) served as reference marks. Fig. 2 gives the energy distribution of the lamp and screen combination. The energy was determined in the spectrophotometric laboratory, visually on a König-Martens Spectrophotometer, by a substitution method of comparison with a radiometrically calibrated Mazda lamp.

The photographic densities were measured on a Hartmann Microphotometer. This method gives immediately the sensitivity of the plate to all parts of the spectrum; but since, during the course of the work, minor changes (change of slit, resilvering of mirror, etc.) were made, the exposure times on different sets of plates were not always equivalent.

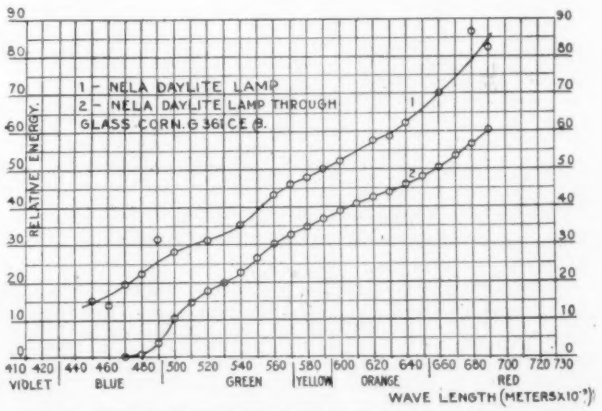

1 - NELA DAYLITE LAMP
2 - NELA DAYLITE LAMP THROUGH GLASS CORN. G 361 CE 8.
RELATIVE ENERGY.
0 10 20 30 40 50 60 70 80 90
410 420 440 460 480 500 520 540 560 580 600 620 640 660 680 700 720 730
VIOLET
BLUE
GREEN
YELLOW
ORANGE
RED
WAVE LENGTH (METERS X 10⁻⁹)

FIG. 2. ENERGY DISTRIBUTION OF THE LAMP AND SCREEN COMBINATION

Furthermore, since the plates were of different kinds and showed markedly different rates of development, they were, in this part of the work, developed by tray until they showed

*Reprinted from, and cuts loaned by, the *Journal of the Franklin Institute.*

[1]Eder, "Handbuch der Photographie," 1902, vol. iii, p. 169 *et seq.* For the Bureau of Standards methods see Bulletin Bureau of Standards, 14, 371, 1917.

[2]Eder, "Handbuch der Photographie," 1902, vol. iii, p. 169. Reference to Schumann, Oct., 1885; Phot. Wochenbl., 1885, p. 395.

[3]*Phot. Jour.*, June, 1895; Eder, "Phot. Korr.," 1903, p. 426. Chapman Jones, *Photo. Jour.*, 1901, 256.

the amount of fog allowable in plates to be used in general photography. The density of the silver deposit obtained depends on the time of development, so that in the curves obtained the shapes (maxima and minima) are the really important parts and the density is only approximately a measure of the speed.

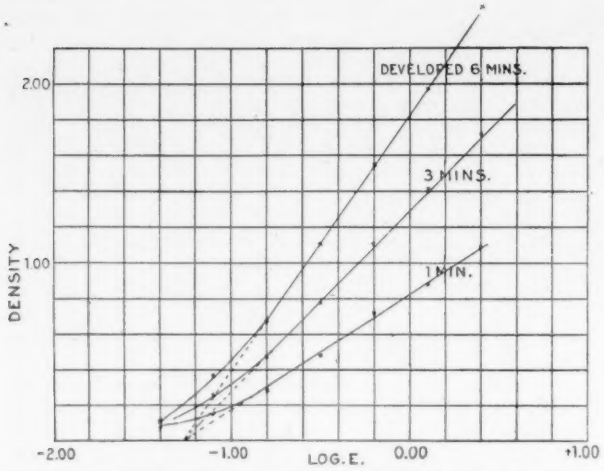


FIG. 3. ILFORD SPECIAL RAPID PANCHROMATIC (5630 N).

Untreated; no filter; speed, 4.45.

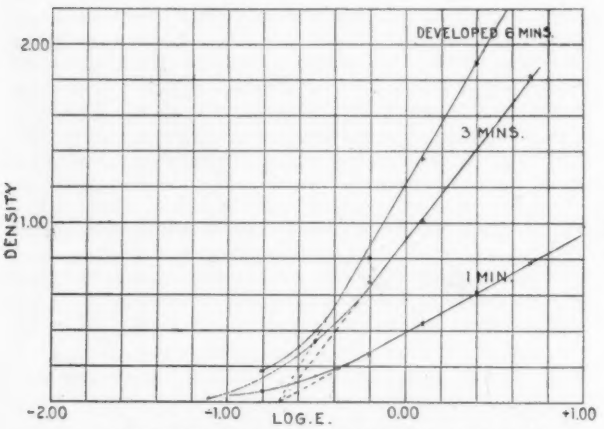


FIG. 4. ILFORD SPECIAL RAPID PANCHROMATIC (5630N).

Treated; no filter; speed, 18.2.

The method generally adopted for the measurement of the speed is that of Hurter and Driffield.[4] Specimens of the plate to be tested are exposed for the same time, behind a sectored wheel, to a standard light source. The transmissions, T, of the images obtained are measured and their densities, defined as $-\log T$, are plotted as ordinates and the logarithm of the time of exposure, E, as abscissas.

The curve so obtained is known as the characteristic curve of the plate. It consists of three parts: the first part is concave upward, the second is a straight line and the third is concave downward. Prolong the straight line part of the curve until it intersects the axis of abscissas. The numerical value of the exposure at the point of intersection is known as the inertia, i, of the plate and the speed is defined as I/i. Hurter and Driffield showed that this inertia of a plate is independent of the kind of developer used (except for strong pyro and for the presence of free bromide) and of the time of development (see Figs. 3 and 4). Free bromides, either in the film or in the developer, shift the point of intersection of the straight line portions of the curves to a point below the axis. The plates for which Fig. 5 gives the characteristic curves contain free bromide in the emulsion.

The Hurter and Driffield speeds for several ammoniated and unammoniated plates were obtained, using an apparatus designed and built by Mr. R. Davis of the Bureau of Standards. The light source (a calibrated tungsten lamp) is corrected for daylight, and means are provided for accurately controlling the current through the lamp, the speed of the sectored disk and the total time of exposure.

PROCEDURE.

A series of Cramer Spectrum Process and Ilford Special Rapid Panchromatic plates were bathed for four minutes at 16° to 18° C. in water containing increasing amounts of ammonia, and were then exposed in the spectograph. Both Metol-Hydroquinone and Pyro developers were used. It was soon found that the plates showed fog in development unless they were kept cool while drying and were dried rapidly. The plates showed a progressive increase in speed with increase in ammonia concentration until, with a bath containing 4 c.c. of ammonia water (containing 20 per cent NH_3) in 100 c.c. distilled water, the plates began to fog so badly in development as to be useless.

The ammonia was then added to water-alcohol mixtures of varying concentrations. The plates bathed in the alcoholic ammonia did not have their sensitivity increased as much

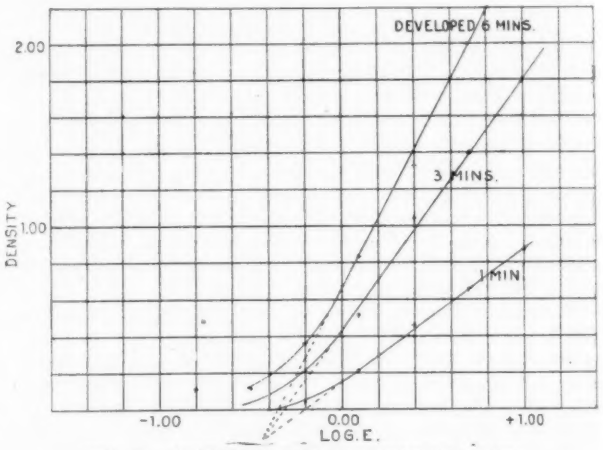


FIG. 5. CRAMER SPECTRUM PROCESS (1439).

Treated; Wratten "F" filter; speed, 1.88.

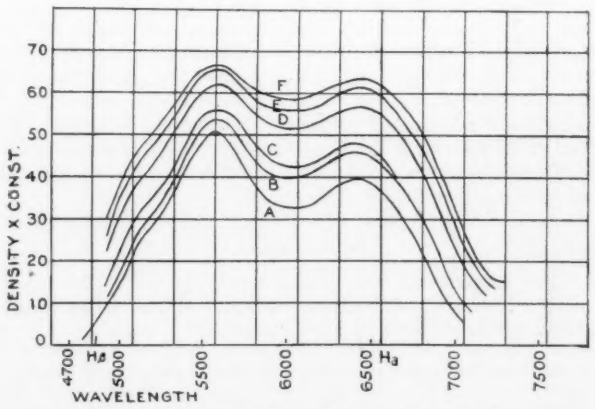


FIG. 6. CRAMER SPECTRUM PROCESS (1439).

A, untreated; *B*, 1/40 c.c. ammonia; *C*, 1/10 c. c. ammonia; *D*, ½ c.c. ammonia; *E*, 1 c.c. ammonia; *F*, 3 c.c. ammonia; 75 c.c. water; 25 c.c. alcohol. Same exposure and development.

[4]Hurter and Driffield, *Jour. Soc. Chem. Industry*, May, 1890, p. 455.

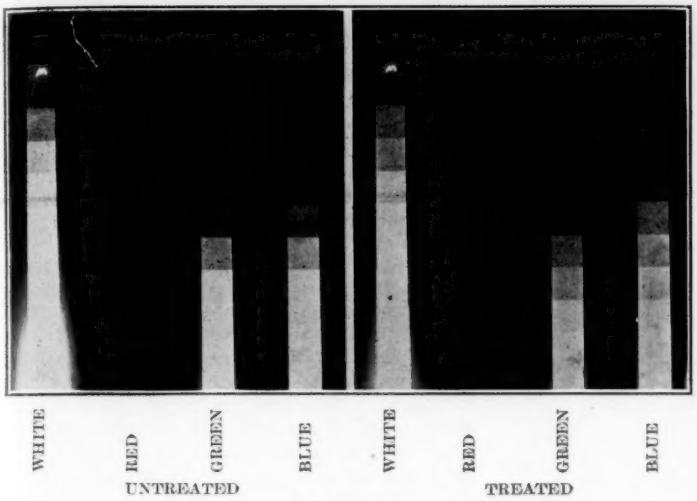


FIG. 7. CRAMER COMMERCIAL ISONON

as in the corresponding water baths, but were very much cleaner working. Seventy-five parts of water to twenty-five of ethyl-alcohol gave the best results, and this proportion was adhered to thereafter. Sometimes the plates showed a slight network of fog (mottling) similar to the drying marks shown when plates are dipped (not soaked) in alcohol to hasten drying. Washing in 95 per cent alcohol for 20 or 30 seconds after the ammonia bath prevented this, but this final wash is not usually necessary, especially if the plates are not forced in development.

Fig. 6 gives the spectral sensitivity curves of a series of Cramer Spectrum Process plates in baths containing 1/40, 1/10, ½, 1 and 3 c.c. of 20 per cent NH_3 ammonia water to an alcohol-water mixture of 25 parts of alcohol and 75 parts of water.

Three to 3½ c.c. of the strong ammonia to 75 c.c. of water and 25 c.c. of alcohol was adopted as the combination to be used, and except for a few trials on various plates, the plates were all treated with this same mixture.

The time of bathing, 2, 4, or 6 minutes, had no appreciable effect, provided that the film was bathed long enough to get thoroughly soaked. Four minutes was the time used for bathing in all subsequent experiments.

For a study of the keeping qualities of the plates, a number of Cramer Spectrum Process and Ilford Panchromatic plates were treated and samples of the treated plates exposed and developed after being stored for various lengths of time. The Cramer plates showed deterioration after a week but were still usable. The Ilford plates were useless after three or four days. The plates which were bathed without the use of alcohol deteriorated more quickly.

The bath of 3 to 3½ c.c. of ammonia water (20 per cent NH_3), 25 c.c. of alcohol and 75 c.c. of water is recommended. Three and one-half c.c. of ammonia water to 100 c.c. of water is used where the maximum increase of sensitivity is desired, but the plates are much more susceptible to fog in development and must be used within a few hours of drying. Development should be carried out, using the Wratten Safelight No. 3 and over-development carefully guarded against.

ORDINARY PLATES.

As is well known, the speed of the silver halide emulsion can be increased by treatment before it is flowed on the plate. This treatment, known as "ripening," is usually either to keep the emulsion at a high temperature for some time or to add ammonia. This ripening by ammonia is effective even after the plates are ready for use.[5]

On ripened plates such as the Seed 30 and Central Special, and on the Seed 23, there is no appreciable increase in speed when they are bathed in ammonia. In some cases there is rather a slight decrease in speed. On one plate known to have been ripened by the ammonia process before coating (Central Dry Plate Co.) which, however, was not fresh, this increase in speed on subsequent bathing in ammonia was quite apparent.

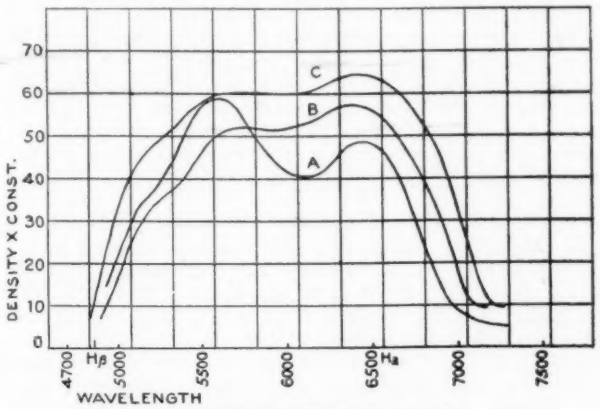


FIG. 9. CRAMER SPECTRUM PROCESS (1439).

A, untreated, 10-second exposure; *B*, treated, 5-second exposure; *C*, treated, 10-second exposure.

Microscopic examination of the treated and untreated plates showed no difference in the size of the grain.

ORTHOCHROMATIC PLATES.

A number of plates sensitive to the green and yellow were tried. Most of them showed no appreciable change in sensitivity. Some had the sensitivity decreased, *e. g.*, Cramer Commercial Isonon. The sensitivity of the Seed Aero Ortho was increased slightly.

Fig. 7 is a print from treated and untreated Cramer Commercial Isonon negatives obtained through the tricolor hensitometer plate. It will be noted that the change in sensitivity can be observed in all the strips.

The Cramer "Trichromatic" showed an increase in sensitivity comparable to that observed in the Spectrum Process.

Treatment of Eastman and of Ansco N. C. films, which are orthochromatic, showed no change

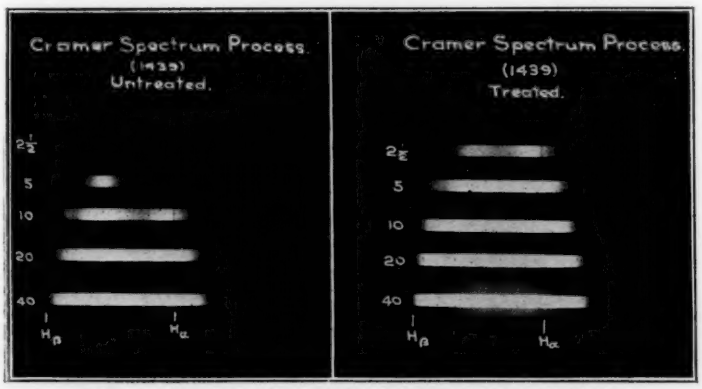


FIG. 8. CRAMER SPECTRUM PROCESS (PANCHROMATIC).

[5]Eder, "Handbuch," iii, p. 63.

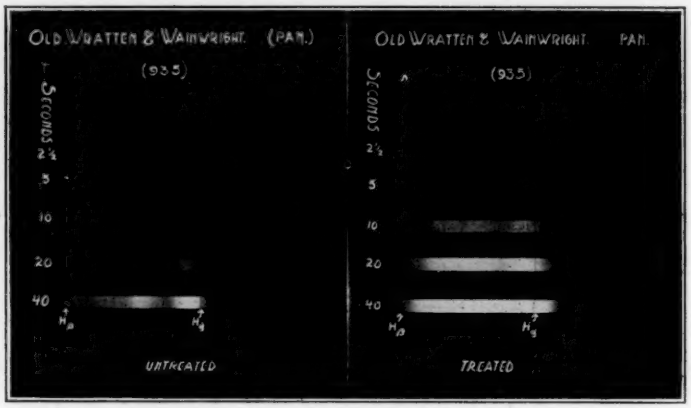


FIG. 10. WRATTEN & WAINWRIGHT PANCHROMATIC.
Expiration date, September 15, 1915. Used Oct. 21, 1918.

larger than the differences that are attributable to experimental errors.

PANCHROMATIC PLATES.

Every panchromatic plate tried showed remarkable increase in speed. The very fast plates, several of which were developed only recently in response to the need for fast color sensitive plates for aerial photography, showed a somewhat smaller increase than the slower and process plates.

This sensitometer plate method gives the relative speeds of plates towards filters, but since the filters do not transmit pure spectral colors (the blue transmits a band in the red and the transmission of the three filters overlap) more can be learned of the color sensitivity from the spectrograph curves.

Fig. 8, a print from a treated and an untreated Spectrum Process Plate, shows the sensitivity of the plate to each wavelength.

Fig. 9 gives the spectral sensitivity curves obtained with the Spectrum Process plate; 5- and 10-second exposures on the treated and 10 seconds' exposure on the untreated plate.

One of the most striking changes produced by the ammonia treatment was the action on old panchromatic plates. A Wratten and Wainwright plate marked "use before September 15, 1915," was exposed on October 21, 1918, in the spectrograph. As was to be expected, the plate was badly fogged on the edges and the sensitivity of the emulsion was much below that of a fresh plate. Treatment with ammonia brought the sensitivity up to an even greater value than that possessed by a fresh plate (see Fig. 10).

The Hurter and Driffield curves for some of these plates gave the following values for the speed:

	Untreated	Treated
	White Light	
Cramer Spectrum Process (1439)..	10.2	25.1
Eastman Experimental Panchromatic IV d	12.6	17.7
Ilford Special Rapid Panchromatic 5630 N	4.45	18.2
Standard Orthonon	23	
	Minus Blue Filter	
Eastman Experimental Panchromatic 2199	1.91	4.37
Ilford Special Rapid Panchromatic 56,416	4.37	13.5
	F. Filter	
Cramer Spectrum Process (1439)..	0.49	1.88
Eastman Experimental Panchromatic IV d	0.57	2.18

The figures give the absolute speeds of the plates to white light and through the Wratten Minus Blue and F Filters on the Hurter and Driffield scale. The value for the speed of the Standard Orthonon plate to white light obtained on the same apparatus is given for comparison. The Minus Blue, a deep yellow filter, cuts out all the blue and violet light, while the F, a deep red, transmits only the long red wave-lengths.

These figures show the remarkable increase in speed of the plates, particularly in the long wavelength region. Thus the Cramer Spectrum Process plates are increased in speed 150 per cent to white light and nearly 400 per cent to the red. Through the Minus Blue filter one of the Ilford plates is increased 300 per cent.

These plates were used in experiments in airplane photography, where for photographing through the haze a fast red-sensitive plate is necessary. Figs. 11 to 13 are a set of prints from the Ilford plates. Figs. 11 and 12 were printed for the same time from the untreated and treated plates. Fig. 13 is from the untreated negative timed to give the best print. The negatives were given the same exposure in the air and were exposed within a few seconds of each other through the Minus Blue filter.

The increased speed of the treated plate is apparent. It will be seen, also, that the treated plate is less contrasty and gives much better detail in the shadows.

Fig. 14 is from a Seed 30 plate used with no filter at an altitude of 17,000 feet on a slightly hazy day. Fig. 17 shows the same scene taken on a treated Spectrum Process plate through the A filter. The pictures were taken simultaneously in a multiple lens camera. The increased haze penetration obtainable by the use of the red filter is clearly shown.

ACTION ON MINIMA.

On every plate which had an irregular curve of spectral sensitivity, the minima were raised and in many cases smoothed out entirely. For example, note the minima at 6100A in Fig. 9.

This property of the ammonia treatment adds greatly to the value of the plates in the photography of spectra, especially as the sensitivity is extended some 200 Angström units further into the red at the same time. The bad effect of a minimum is, however, smoothed out to some extent in ordinary photography through filters.

PLATES WITH KNOWN DYESTUFFS.

The difference in behavior between the ordinary and orthochromatic plates and the panchromatic plates shows clearly

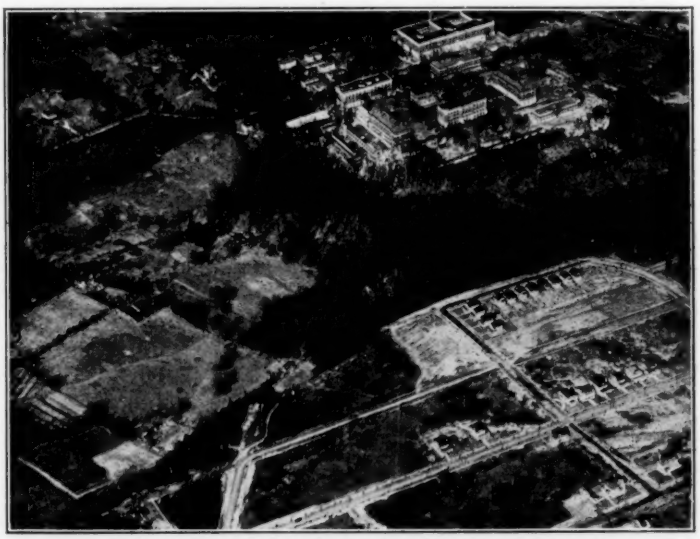


FIG. 11. AMMONIATED PLATE. PRINTED 21 SECONDS.
Hypersensitized Ilford plate. 1/130 second exposure. Minus blue filter. Oblique from 4,000 feet.

that the sensitivity increase dealt with here is not that observed by Eder, which is due to "ripening," but is an action associated with the dyestuff.

The effect of the ammonia is to increase the sensitivity of the emulsion to the incident light and not to increase the developability of a latent image already formed, since a plate treated with ammonia after exposure but before development showed no increase in sensitivity. That the action is not due to the alkalinity of the bath is shown by the fact that bathing in a solution of sodium hydroxide having the same concentration of OH ions had no effect on the speed of the plate.

Part of the increase in speed is, probably, due to the fact that some of the dyestuff in the gelatine film is washed out and its screening effect diminished. The ammonia bath becomes colored with use and a color difference is observed between the untreated and treated plate before development.

The pinaverdol dyes sensitize for the green and yellow and an orthochromatic plate containing one of this series of dyes has the sensitivity increased by the ammonia treatment. Fig. 15 is a plate made up by the Cramer Dry Plate Co., using pinaverdol Pv. I., made by the Bureau of Chemistry, and marked by Cramer "similar to Trichromatic." The Trichromatic plate has the sensitivity curve of a pinaverdol dyed plate and Fig. 16 gives the curve before and after ammonia treatment.

Mixtures of pinaverdol and pinacyanol are the dyes usually used in the preparation of panchromatic plates intended for spectrum photography. The mixture of these two dyes alone leaves a strong minimum at about 6100A. The ammonia treatment smooths out the minimum. In many plates intended for general photography other dyes are added to sensitize in this region.

Fig. 18 gives curves for a plate (similar to their Spectrum Plate) made up by the Cramer Co., using a mixture of the Bureau of Chemistry's pinacyanol, Pc. XII., and pinaverdol, Pv. I. It will be noted that the addition of pinacyanol lowers the maximum due to the pinaverdol.

The dyes used in sensitizing are nearly all basic dyes, and it is not probable that the ammonia changes the dye itself. On the addition of ammonia to the dye solution before bathing, there is no color change. It is possible that the solvent action of the ammonia on the silver halide facilitates the reaction between the dyestuff and the silver salt, in addition to its softening effect on the gelatin. This, however, does not account for the raising of the minima. It is possible that there is the formation of a $AgNH_3Cl$+Dyestuff molecule with a photosensitiveness slightly different from that of the original molecule.

FIG. 12. UNTREATED PLATE. PRINTED 21 SECONDS

Ilford panchromatic plate. 1/130 second exposure. Minus blue filter. Oblique from 4,000 feet.

FIG. 13. UNTREATED PLATE. PRINTED 8 SECONDS

Ilford panchromatic plate. 1/130 second exposure. Minus blue filter. Oblique from 4,000 feet.

SUMMARY.

Since ammonia, when added to the dye bath in preparing bathed plates, increases the sensitizing action of the dye, its action on commercial plates was investigated.

In the course of the work three methods of sensitometry were used. Of these, one was used as a first qualitative test; the second, the spectrograph method, was used to study the effect of the ammonia on the sensitivity of the plate to each wave-length; the third, the Hurter and Driffield method, gives the absolute value of the speed of the plate.

It was found that by bathing commercial panchromatic plates in a solution of 25 cubic centimeters of ethyl-alcohol, 75 cubic centimeters of water, and 3 cubic centimeters of strong ammonia water (20 per cent NH_3) for four minutes at 18 degree centigrade and drying rapidly, the speed to white light is increased 100 per cent in nearly all cases, and the sensitivity in the red portion of the spectrum is extended one hundred or more Angström units. The speed in the red portion of the spectrum is increased, in many cases, 400 per cent. If the plates be bathed without the alcohol (100 c.c. water, 3½ cubic centimeters of ammonia water) the speed is still more increased, but the plates should be used immediately after drying.

Ordinary plates do not have their sensitivity appreciably changed. Most brands of orthochromatic plates are not improved, although one, the Cramer Trichromatic, showed the same increase as the panchomatic plate.

My thanks are due to Dr. J. S. Ames for his supervision of the present investigation and for valuable advice which he rendered during many conferences.

The energy distribution of the light source in the spectrograph was determined by Mr. E. P. T. Tyndall and Mr. H. J. McNicholas of the spectrophotometric laboratory. I am also indebted to

FIG. 14. SEED 30 PLATE, F/11. NO FILTER

30° oblique from 17,000 feet. Hazy day. 1/100 second exposure. Taken simultaneously with Fig. 17 in a multiple lens camera.

Mr. R. Davis and Mr. F. M. Walters, Jr., through whose help the Hurter and Driffield curves were obtained, and to Dr. C. C. Kiess, under whose direction and coöperation most of the work was done.

THE ORIGIN OF OCEANS AND THE ARCHITECTURE OF THE EARTH.

AT a meeting of the Oceanographic Institute, held Dec. 6, 1919, a novel, attractive and interesting theory of the formation of oceans was expounded by M. Belot. The hypothesis is of especial interest since it undertakes to explain not merely ocean formation but also the peculiarities of the architecture of the earth. M. Belot has subjected known data to calculation and has deduced logical conclusions, taking as his starting point the following hypothesis: The earth at the moment when it was in one of the first stages of the condensation of its nebulous matter, *i. e.* while it was a fluid, incandescent, anhydrous, spherical nucleus, was animated by two movements: namely, the rotation around the line of its present poles and the other the movement of translation from south to north along the line of these poles. These two movements exist at the present time—consequently the hypothesis is entirely admissible. Furthermore, there is no other hypothesis, whether astronomical or geological, which when subjected to test by calculation and observation permits the explanation of all the facts, both present and ancient. We may mention in particular that the theory of present causes, which is accepted as a dogma in geology and as the very foundation of this science, is absolutely powerless to explain all the said facts.

If we accept the theory formulated by M. Belot, events must have occurred in the following manner:

When the anhydrous nucleus, surrounded by an atmosphere which exerted upon it a pressure approximately equal to 360 of our present atmosphere had radiated sufficient heat into interstellar space to reduce its temperature to somewhat above 1,300° C. water was able to form, but must have been still in the state of vapor, since the aforesaid temperature is that of the dissociation of the elements of water and is much greater than its critical temperature 365° C. (the critical pressure of water being 194 atmospheres). When the temperature had fallen to 1,100° C. the materials which were destined to form the solid crust of the terrestrial globe solidified around the austral pole, forming a cap along whose edge detached blocks appeared, which, floating upon the surface of the liquid nucleus, finally detached themselves to the mass surrounding the boreal pole, thus constituting the foundation of the continental masses now existing in the northern hemisphere. Then, as the cooling process continued, the solid mass if the austral pole extended towards the north and joined the boreal mass. Thus was formed the crust of the earth.

At a temperature of from 800° to 700° C. the haloid salts, which had previously existed in the atmosphere in a state of vapor, fell in the form of rain upon the austral cap, there forming masses of considerable extent which would represent at the present time a uniform thickness of 45 m. over the surface of the globe.

When the temperature had fallen to 365° C., *i. e.* the critical temperature of water, the latter became able to exist in the liquid state and was precipitated in the form of rain almost instantaneously upon the austral "cap" of the earth. Like the masses of matter which had been previously solidified or precipitated this water was transported from the south to the north, and far more easily than the materials forming the

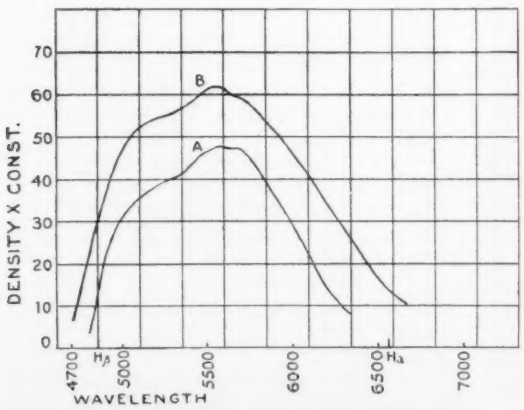


FIG. 15. G D IV. PvI (similar to trichromatic)

A, untreated, 10 seconds exposure; *B*, treated, 10 seconds exposure.

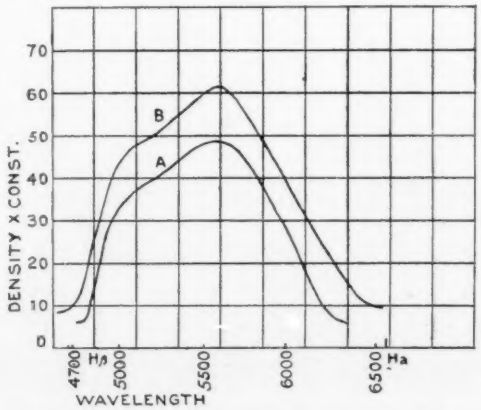


FIG. 16. CRAMER TRICHROMATIC, NO. 21

A, untreated, 10 seconds exposure; *B*, treated, 10 seconds exposure.

crust of the earth by reason of its fluidity; in its passage toward the north it carried with it to begin with the haloid salts and then sheared off the surface of the austral continent for the benefit of the boreal continents. This action must have exhibited extraordinary intensity by reason of the great rapidity at which the water traveled as well as of its high temperature and of the enormous pressure which it exerted upon the bottom of the ocean, since this first austral deluge represents a layer of water covering the entire surface of our present globe to a depth of 1600 m.

When the temperature of the atmosphere, continuing to decrease, had fallen to 1,100° C. the austral pole was the seat of a second deluge, even more abundant than the first (representing a depth of water of 2,000 m.), but less erosive in character. The solid austral masses of matter were nevertheless again sheared off and the material transported towards the north, being deposited upon the foundation previously laid down and forming marine deposits which gave to the continents the broad outlines they have at present, *i. e.* the roughly triangular form pointing toward the south which they all possess, and thus modelling the terrestrial surface in almost the shape it presents at present, with a predominance of masses of earth in the northern hemisphere and of oceans in the southern hemisphere.

It was in this manner that the oceans were formed and it is evident that they were hot in the beginning and hat they have always been salty, in fact more salty, at first, than they are at the present time, since they were then fully saturated with mineral salts, as is indeed the constituent water of all rocks, since this constituent water is fossil sea water.

The austral continent, whose importance has been proved by the recent expeditions to the south pole, is merely the remainder—as we may say the non "decapitated" remainder of a continent which was originally 33 times as extensive as at the present time; the rest of the material originally composing it has served to form the boreal continents and the deposits which lie beneath the deep seas.

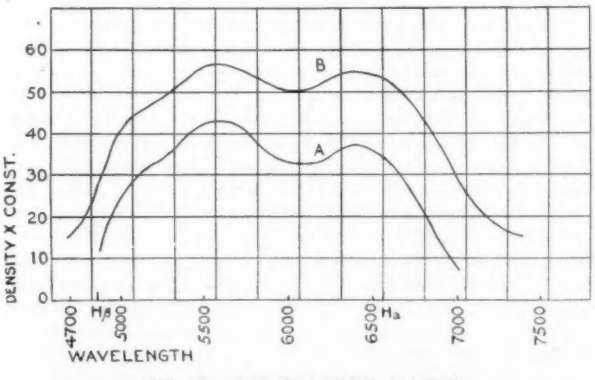


FIG. 18. G D III. PcXII and PvI

A, untreated, 10 seconds exposure; *B*, treated, 10 seconds exposure.

All known facts that are of primary importance or merely accessory, as well as all the most recent discoveries in geography and in chemistry and the physics of the globe, confirm this theory of austral deluges formulated by M. Belot. Some of these may be mentioned here.

The great ocean depths have always existed, and existed in the very localities where they are now found; the existence of a sea surrounding the north pole is explained by the formation of a depression around the north pole at the time of the first solidification of the crust of the earth.. The dense red clay found at great depths has never left these ocean depths and has never taken part in the formation of the sedimentary strata of the continents of the northern hemisphere. This clay is highly ferruginius in character and its presence explains the recently discovered effect which these great ocean depths of the austral continents exert upon the magnetic needle.

The theory of austral floods also explains the method in which radio-active elements are distributed in the sub-soil and the formation of the deposits of metallic ores and veins of metal and metamorphic rocks. These great austral floods which no human eye has ever seen, these great movements, have nothing in common with the flood described in the Bible, nor with the fluctuations of the sea which have modeled the surface of the earth at different geological periods. The latter are movements of great insignificance compared with those first translations of matter described above, and their effects have been almost entirely confined to the northern hemisphere.

FIG. 17. HYPERSENSITIZED CRAMER SPECTRUM PROCESS PLATE. F 4.5. WRATTEN "A" FILTER

30° oblique from 17,000 feet. Hazy day. 1/100 second exposure. Taken simultaneously with Fig. 14 in a multiple lens camera.

MAGNETIC AND MECHANICAL TESTING OF IRON.

MAGNETIC tests have been limited hitherto to magnetic purposes, but attempts have recently been made to substitute such tests in place of mechanical tests for determining the physical properties of the ferrous group of metals.

Magnetic tests, however, require exact laboratory work, not always applicable to workshop conditions and the vague nomenclature in vogue does not facilitate their study.

The question, therefore, arises: are the magnetic properties of commercial iron sufficiently uniform and, in their interpretation, sufficiently definite, to reveal mechanical defects in the metal by irregularities in the magnetic tests. The evidence so far is promising, if not conclusive.

The simplest way of magnetic measurement of rails is the ring method. A ring is wound with the magnetizing primary, over which is placed a few turns of the secondary winding, in circuit with a d'Arsonval galvanometer. In the testing of ball-bearing races, ritary hysteresis measurements have been substituted for the throw of a ballistic galvanometer.—Abstracted from *Engineering* by *The Technical Review*.

Science and National Progress

Edited by a Committee of the National Research Council

Dr. Vernon Kellogg, Chairman, Dr. R. M. Yerkes, H. E. Howe

PRACTICAL MENTAL MEASUREMENT.

Intelligence Tests for Elementary Schools.

By ROBERT M. YERKES,

Chairman of the Research Information Service of the National Research Council, Washington, D. C.

The National Research Council is a cooperative organization of the scientific men of America. It is established under the auspices of the National Academy of Sciences and its membership is largely composed of appointed representatives of the major scientific and technical societies of the country. Its purposes are the promotion of scientific research and of the application and dissemination of scientific knowledge for the benefit of the national strength and well-being.

THE purpose of this article is to announce methods of group intelligence examining which have been prepared under the auspices of the National Research Council for use in our elementary schools, and particularly in grades three to eight. These methods are practically completed and arrangements have been made with the World Book Company of Yonkers, New York, for the manufacture and distribution of all materials necessary for the conduct of examination.

Fortunately the essential materials are extremely simple, consisting merely of the record blank, a printed key for the scoring of the papers, and a little book which gives full directions for the conduct of the examination and use of results. It is expected that the "National Intelligence Tests," as these examinations are to be called, will be published during the spring of 1920.

In order that these methods may be self-improving, it has been arranged between the National Research Council and the World Book Company that the ordinary commercial profits on the publications shall be used for the expense of research on methods of psychological examining and their useful applications.

Oddly enough man has given vastly more attention to the control of inanimate nature and of the lives of other living things than to that of his own behavior. Largely because of the lesson of the war, this situation seems likely to change rapidly and radically. For among other things the great conflict emphasized in an unusual manner the importance of definite knowledge of human traits and of ways of utilizing them to advantage. It became clear to thousands of men and women who had to deal with military problems that the practical classification of men by various sorts of physical and mental measurement is essential to the achievement of efficient work.

Although it has long been recognized that physical characteristics must be considered in connection with occupational choice and the kind and amount of work which may reasonably be expected of a man, it is largely because of our war-time experiences that we have come to recognize widely the similar importance of considering mental qualities and capacities in their relations to vocation and to the varied social demands.

Man's mental constitution is just as complex as his physical body and as highly variable. But fortunately it is possible for us to measure certain at least of the important traits or qualities of mind almost as readily as we measure height, weight, muscular strength, endurance, and numerous other physical characteristics. It is not a simple task to prepare a practically useful description of the mental make-up of a human being for there are many important traits or aspects of mind which are significant and must be measured. It is common to think and speak of mind as consisting of intelligence, feeling, and will, but even if these terms are made to include all aspects of mind each designates a complex group of facts and further analysis is necessary.

Most of the mental measurements which are being made for practical purposes in our schools, hospitals, prisons, reformatories, factories, and in our army and navy, are really measurements of one or another sort of intellectual processes, such, for example, as memory, constructive imagination, the ability to think simply or to reason. But quite inseparable from what are properly called intellectual processes are other processes which are usually termed feelings or emotions. These chiefly determine the temperament and possibly also the character of the individual, and so it happens that even although a person may be intellectually able and competent for a certain sort of task he may be quite unfit for the task because of emotional or, better still, temperamental characteristics.

The accompanying figure (1) indicates certain differences in the intelligence of two individuals. X was a sergeant in the United States infantry, thirty years old, a teamster who had progressed in school as far as the fourth grade, and before entering the army received $18 a week wages. Y was a private in the infantry, twenty-three years old, a tool dresser by trade, with eighth grade education, and received before entering the army $49 per week. The figure shows how strikingly these two men differ with respect to eight groups of intellectual measurements.

Fig. 2 similarly indicates the differences for eight mental tests among three groups of army officers, namely: medical officers, chaplains, and engineers. These differences are in many respects surprising and make one wonder whether they are inborn or the result of education and professional experience. They may possess major vocational significance.

A really useful description of the mental make-up of any person must rest, then, upon measurements of many mental traits. This is just as true for the practical applications of psychology as for disinterested research. A man may have intelligence enough to succeed as a carpenter but he may lack the desirable sorts of mechanical skill and it may be extremely difficult or impossible for him to acquire them. An army officer may be highly intelligent and eager to lead but because of deficiency in the combination of emotional, volitional, and intellectual traits which determine leadership, he may be wholly unsuccessful in his profession. Again, the salesman may fall short of the requirements of his occupation because of temperamental characteristics or because of inadequate intelligence.

It is now many years since Alfred Binet in Paris demonstrated, by the use of very crude methods, the possibility of classifying children with respect to mental make-up so that educational work might be facilitated and the individual child given better opportunity for development. The influence of Binet's work has been world-wide. It has stimulated alike endless improvements in methods of mental measurement and practical applications of the results which these methods made available. The war supplied an opportunity for a convincing demonstration of the importance of psychology in daily life and the preparedness of the profession to be useful. There were few if any greater surprises in the war than this exhibition of the practical value of psychological

methods. Almost over night there developed in America the conviction that psychology can be made serviceable, not only in education as heretofore, but similarly in all of the professions and even in the industries. It has been said by those who should know that the suggestion of the academic, abstract, and impractical given by the word psychology very nearly rendered impossible the introduction of methods of

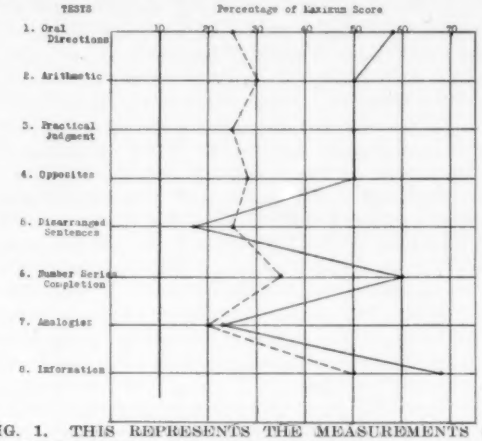


FIG. 1. THIS REPRESENTS THE MEASUREMENTS OF INTELLIGENCE FOR TWO SOLDIERS, X (———) AND Y (- - - -)

mental measurement and classification in the United States Army. It is the more surprising, therefore, that today psychology should be a word to conjure with in the military service. Yet, this is undoubtedly true, and that not because of political influence or of over-suggestibility, but because of the demonstration from day to day, in scores of training centers and in thousands of military organizations, of the ability of the psychological examiner, by means of his almost ridiculously simple methods, to classify men according to intelligence as very superior, superior, high average, average, low average, inferior, and very inferior. For convenience these

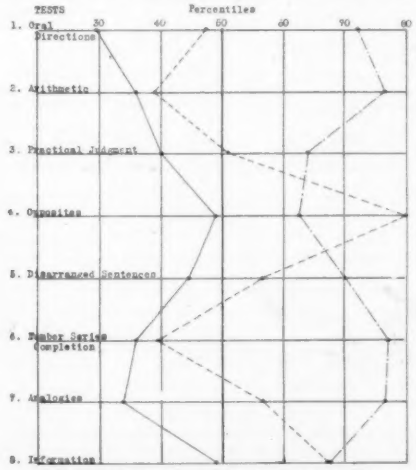


FIG. 2. DIFFERENCES IN THE INTELLECTUAL MAKE-UP OF THREE GROUPS OF ARMY OFFICERS: MEDICAL OFFICERS (———), CHAPLAINS (- - - -), AND ENGINEERS (—.—.—), AS INDICATED BY THE EIGHT TESTS OF THE ARMY GROUP EXAMINATION ALPHA

several groups were usually designated in the army by the letters A, B, C+, C, C—, D, and D—.

Another reason for the amazing success of psychological work in the army was the wholesale demonstration of the fact of marked differences in intelligence among individuals. Although this has long been known to psychologists and to others who have given any considerable amount of attention to the observation of mental traits, people in general had not thought enough on the matter to have any opinion. Army psychologists suddenly supplied the necessary data to create an opinion.

Such charts as those reproduced in Figures 3 and 4 fairly indicate the degree of intellectual difference among important army groups. Almost everyone grossly overestimates the average intelligence of human beings, and similarly underestimates the range of difference in intelligence. Compare, for example, the distribution of intelligence among the several letter-grade groups A to D— of the enlisted men in the United States Army who could read and write English fairly well, as represented by the heavy solid line of the figure, with the distribution of commissioned officers of the army, represented by the light solid line. Whereas enlisted men occur in considerable numbers in all grades of intelligence from the highest to the lowest, but most frequently in the average of C grade, officers are mostly of either A or B, that is, very superior or superior intelligence. A few are found to fall in the C or C+

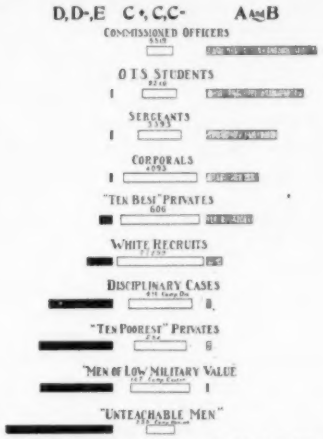


FIG. 3. THE DISTRIBUTION OF INTELLIGENCE GRADES FOR SEVERAL IMPORTANT ARMY GROUPS

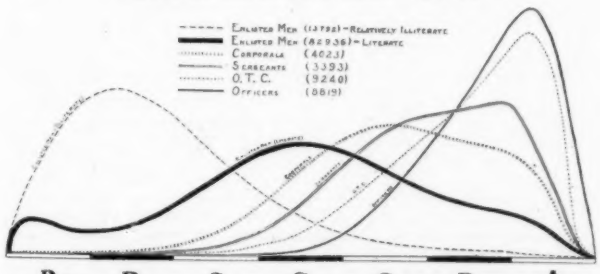


FIG. 4. THE PROPORTIONS OF LOW, AVERAGE, AND HIGH GRADE MEN IN TYPICAL ARMY GROUPS

groups, but there is none in the D group and only an occasional unsuccessful individual in the C— category.

A still more impressive exhibit of difference in intelligence among army groups, and of the practical significance and relationships of intelligence, is supplied by Fig. 4. For simplicity of representation the several grades or levels of intelligence in this chart are arranged in three groups which may be designated as high, medium, and low. Low intelligence is always represented in the figure by the solid black bar, medium intelligence by the white bar, and high intelligence by the shaded bar. It is noteworthy that commissioned officers are all found in the medium or high intelligence groups, while by contrast men designated by their officers as utterly unteachable fall without exception either in the low or the medium intelligence groups. The contrast between the intelligence of the ten best privates and the ten poorest privates, as selected by company commanders, also is worth noting; and the acute reader will not overlook the practical importance of the fact presented by this figure that disciplinary

cases in the army are usually of low grade or medium intelligence and very seldom of high intelligence. It is a natural inference from this figure that had the army rejected the ten per cent of recruits with lowest intelligence, the last four groups of Fig. 4, namely, those designated as disciplinary cases, poorest privates, men of low military value, and unteachable men, would have been reduced so considerably—probably as much as fifty per cent—that army costs and efficiency of training would undoubtedly have been effected to the extent of millions of dollars.

The press early in the development of military psychology seized upon the methods and results of psychological examining as items of news which would appeal to the public. This proved to be true and psychology owes to the magazines and newspapers of the country a degree and quality of publicity which has multiplied many fold both the interest in psychology as science and as technology and the demand for its useful applications. This demand grew so rapidly during the war that the Division of Psychology of the Surgeon General's Office was much embarrassed by the requests from industrial concerns, educational institutions of all sorts, and individuals for the army methods or their equivalents. Similar demands overwhelmed the Committee on Classification of Personnel of the Army, which was engaged primarily in occupational classification and trades testing. At the moment it was impossible to respond satisfactorily to these demands, however reasonable or urgent they might appear. But with the cessation of hostilities the psychologists of the country hastened to show their good will and their eagerness to be of service in non-military ways.

There was organized for the intelligent, systematic study of psychological and other personnel problems in industry The Scott Company, with offices in Philadelphia and Chicago. There were promptly developed methods of examining college students or other groups of mature individuals. Indeed, for this purpose the army method of examining men by groups, which is usually spoken of as 'army alpha,' and which consists of eight different tests of intelligence, has been used for the classification of students in upward of fifty colleges and normal schools. Otis, Thorndike, and Thurston, within a few months of the signing of the armistice, made available group methods of measuring intelligence which are primarily useful in institutions of higher learning. But it remained to provide methods suitable for the classification of children in our public schools.

There had been abundant indication of the interest of public school authorities in the army methods and of their desire to secure equally serviceable methods for school use. The need was clearly urgent. Consequently the writer, in coöperation with Lewis M. Terman, presented the matter to the General Education Board of the Rockefeller Foundation, with the suggestion that the preparation of methods of psychological examination suitable for use in grammar schools might be financed by the Board. This suggestion was favorably received and arrangements were subsequently made by which the National Research Council, with the assistance of an appropriation of $25,000, should direct the preparation of methods. In the spring of 1919 a committee consisting of Dr. M. E. Haggerty, Dr. L. M. Terman, Dr. E. L. Thorndike, Dr. G. M. Whipple, and Dr. R. M. Yerkes, was organized by the Research Council to undertake this work. This committee acted promptly and energetically. It systematically surveyed the tests which were available for use and from among them selected something more than twenty kinds for preliminary trial. Many different forms of each of these twenty tests were prepared at considerable labor and expense. Some idea of the nature and variety of these tests is given by the following reproductions of the introductory exercises which were used. Thus, Test 1, as it appears, demands the completion of certain pictures. It should be emphasized that these figures are not complete tests but merely odd samples to indicate the nature of the tests. Test 2 demands the numbering of the pictures in logical order, so that they shall tell a story or indicate the

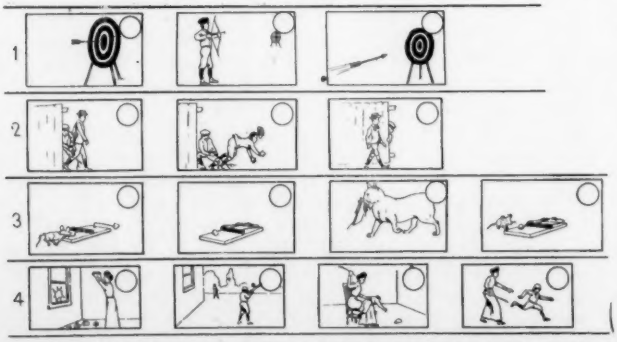
NVA

TEST 1

Look at each picture and draw in the part that is left out. Don't try to make it pretty. Make just enough marks to show that you know what is left out. If the drawing is too hard you may write one or more words to show what is left out.

NVB

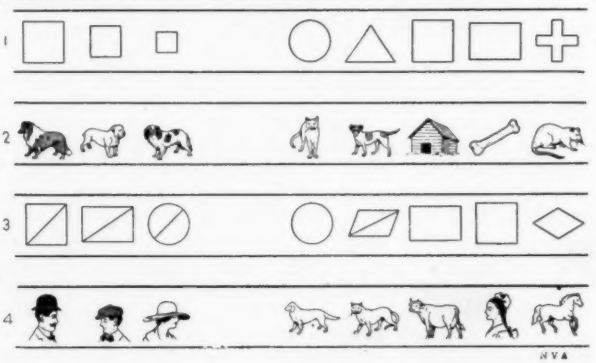
TEST 2



NVB

TEST 3

Look at each row of pictures. The first three in each row are alike in some way. Find the one other drawing in the same row that is most like the first three and put a cross under it.



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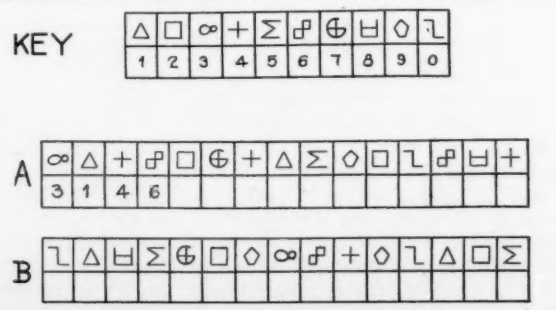
TEST 4

Make under each drawing the number you find under that drawing in the key.



MENTAL TESTS FOR SCHOOL CHILDREN PREPARED BY A COMMITTEE OF THE NATIONAL RESEARCH COUNCIL

natural sequence of events. Test 3 demands comparison and the recognition of degree of similarity. Test 4 demands rapid habit formation and memory.

These tests were given to more than 5,000 children late in the spring of 1919. The results were then carefully studied and from among the tests which had been thoroughly tried ten were selected for further use. These were finally arranged in two groups, five tests each. The first group is to be called Examination A, or Intelligence Scale A. It consists of: (1) a test of arithmetical reasoning; (2) a sentence completion test; (3) a logical selection test; (4) a synonym-antonym test; (5) a symbol digit test. The second group, designated as Examination B, or Intelligence Scale B, consists of: (1) a test of computation; (2) an information test; (3) a vocabulary test; (4) an analogies test; (5) a comparison test.

Either of these two examinations may be given to an entire class in a period of thirty minutes. For the hasty survey of a school system in order to obtain a rough classification of the children by intelligence, either Examination A alone or Examination B alone may be used, but for more careful and accurate classification it is recommended by the committee that Examination A be given one day and Examination B at least one day later.

The examination papers can be scored rapidly by the use of printed keys or stencils which indicate exactly how the various items in each test should be answered. A child must be able to read English as well as the average third grade pupil in order to take these examinations satisfactorily, but the examinations demand very little writing, since, as in the case of the army examination, the responses to the tests are mostly indicated by making such simple marks as a cross, a circle, or a line in the appropriate place. For this reason the work is fairly easy and pleasant to the average child.

Each test in these examinations consists of from 15 to 40 different items, arranged in order of increasing difficulty. The first few items are usually so easy that a child of six to eight years can readily respond in the right way, but before the end of the test is reached the items have become so difficult that even a twelve-year-old child will frequently fail. A limited time is allowed for each test and this time is so fixed that only a few, and those the very quickest and brightest children, can possibly finish the test.

These intelligence examinations supply a reasonably accurate measurement of the intellectual ability of each child examined. The measurements may be expressed either in terms of the number of points scored in the examination, by letters as in the army, or by indicating where the child belongs in the group of American school children, as, for example, among the highest five per cent. It is unquestionably important that reexamination be made once or twice a year, in order to verify or correct the intelligence rating and classification, so that no injustice shall be done the individual. Heretofore the psychological examining of all children in the public schools has been practically impossible because each individual had to be examined separately and alone, the time varying anywhere from thirty minutes to an hour. Under these conditions only children who failed to make satisfactory progress or were difficult to manage could be given examination, for the examiner never had the time or assistance to classify all pupils. The group method of examining radically alters the situation, for it makes it possible to examine an entire class in the time that it formerly took to examine a single pupil.

The individual examination, it is true, ordinarily supplies a somewhat more reliable measure because in any group some individuals are likely to fail, for one reason or another, to do justice to their ability. This, however, is merely an argument for re-examination by the group method in order that the chances of serious injustice may be minimized.

The really important contribution of the group method of psychological examining to educational classification is the school survey. It will undoubtedly become the practice in progressive school systems to examine all pupils psychologically for the purpose of intelligence classification at least once each school year and possibly twice. This kind of survey can be carried out with very little extra expense to the school, because the methods in question can be used effectively by any intelligent teacher who has had a few hours of intensive training in this kind of work. The results are wholly objective, that is, independent of the judgment of the teacher as to how the items of the test should be answered, and likewise independent of the teacher's previous estimate of a child's ability. On the child's school record card the intelligence rating should be entered, just as the address, age, school grade, and so on, are recorded. It is merely an additional item of information concerning the pupil, but as it happens it is one of the most important items for educational and vocational purposes that can possibly be made available.

Although the school survey or wholesale classification of children by intelligence is likely to play a conspicuously important rôle in future educational development, it is quite clear that methods of individual examining should be continued and improved, for the group method of examining will constantly bring to the attention of teachers and of psychological specialists in school systems pupils who are mentally exceptional in one way or another. Some will be exceptionally dull or backward; some just the opposite; others will exhibit peculiarities of emotional life or of temperament which seriously interfere with school work. In any case a careful individual examination by a thoroughly competent person is urgently desirable and is indeed due the child.

A NEW METHOD OF DETERMINING THE SPEED OF SOUND IN THE WATER.

THE first attempts at determining the speed of sounds in water were made by Colladon and Sturm at Lake Leman in 1827, the results forming an accepted standard. Various physicists, however, have studied the problem in more detail since then in the interests of greater precision. For example, they have endeavored to ascertain the possible influence of the temperature of the water and of the presence of dissolved liquids or gases in water. A French scientist, M. Marti (the author of a system to take ocean soundings by the acoustic method, *i. e.* by measuring the time required for the noise of an explosion occurring at the surface of the water, to return to the latter after being reflected from the bottom), has recently renewed his researches with respect to the velocity of sound in sea water under given conditions of temperature and of salinity. M. Marti's experiments were made in the roads at Cherbourg at a depth of about 13 meters. Three deep water microphones were anchored in the same alignment parallel to the great dike at a distance of about 900 meters from each other. The sound waves were produced by the detonation of explosives placed upon the same alignment as that of the microphones at least at a distance of 1,200 meters. The passage of the front of the wave to the different microphones respectively was registered by means of a standardized tuning fork and a recorder. Under the conditions then existing the velocity of the sound wave was about 1503.5 meters per second at a temperature of 14.5° C. with a density of water of about 1.0245. M. Marti estiniated that the possible error ought not to be more than 50 centimeters, *i. e.* 1/3,000 of the value. These figures differ perceptibly from those given by Colladon and Sturm who found the speed of propagation per second to be 1,435 meters in Lake Leman at 8° C. Marti found it to be 1,399 meters in distilled water at 4° C. while Doersing gives it as 1,441 meters in water containing no air at 13° C. and 1,470 meters in a 1/10 solution of chloride of sodium (common salt) at 15° C.

Survey of Progress in Mechanical Engineering

Prepared Under the Auspices of the American Society of Mechanical Engineers

DUPLEX CAR AND ENGINE.

DESCRIPTION of a light British car with an unusual type of engine.

The Duplex motor is of the single-sleeve duplicated-piston type with the pistons running in conjointly twined cylinders.

The motor, Fig. 1, consists of a detachable headed monoblock of 8 cylinders of only 56 mm. (2.20 in.) bore by 75 mm. (2.95 in.) stroke.

The ports, inlet and exhaust, are cut half around the outer side of each cylinder and are opened and closed by crankshafts through tiny connecting rods attaching to lugs at the bases of the sleeves (Fig. 2). These sleeves which are of cast iron carry three rings each, the top one wider than the

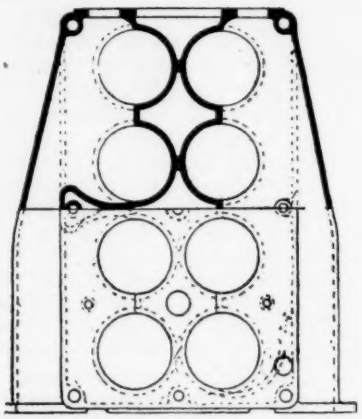


FIG. 1. DUPLEX SLEEVE VALVE MOTOR, PLAN VIEW WITH HEAD BLOCK DETACHED, SHOWING THE SEMI-CIRCUMFERENTIAL PORT AREAS

other two and as the ports are 5/16 in. deep on the exhaust side and ¼ in. deep on the inlet, the construction gives a large valve area with a comparatively slight sleeve motion (1⅛ in.).

The pistons carry their three rings on the middle of their trunks and the gudgeons rather lower than usual, because of the connection in each pair to a common crankpin on the short 4-throw crankshaft.

The crankshaft is mounted at the ends only in two roller bearings, the rollers being hollow to enable them to be link-caged and distanced somewhat like the rollers in a chain. The sleeve shafts, on the other hand, are mounted in long plain bearings with bolt thrusts at the end and drive is by helical gearing from the front end of the crankshaft. The sleeve shaft also carries an eccentric actuating a horizontal piston pump internally spring loaded which draws oil from a large deep rearward pump by way of a non-return ball valve (right-hand side of Fig. 2) and delivers it downward again to a gallery lead in the casting for distribution to four transverse troughs from which dippers on the big ends effect splash lubrication to all interior surfaces.

It is claimed that this design permits obtaining rather interesting physical results; namely, a cylinder capacity of approximately 80 mm. (3.15 in.) by 75 mm. (2.95 in.) halved in area so as to produce a simultaneous effort under the medium long stroke or internal combustion conditions of 56 mm. (2.20 in.) by 75 mm. (2.95 in.). It is claimed that in this manner all the capacity of the short-stroke type is obtained for sustained high speed without its extravagance and jerky inflexibility at low and medium speeds. In fact, it is claimed that the motor is obtained in which the power curve comes practically in a straight line from the rated 10 h.p. at 1,000 r.p.m. up to 33 h.p. at 3,000 r.p.m.

As regards the valve mechanism, it is stated that the valve shafts having only frictional resistance to overcome are doing next to no work and their rotation absorbs little power, while the system affords easy timing. It is claimed the motor presents unusually good cooling facilities.—*The Auto Motor Journal*, January 15, 1920, pp. 66-68.

PRODUCER GAS FOR MOTOR VEHICLES.

GENERAL discussion of the advantages and disadvantages of the use of producer gas for motor vehicles, followed by a description of some attempts to do it on a practical scale—among others, those made by the author of the paper himself.

In the opinion of the author the ordinary producer is larger and heavier than it might be and one of the reasons for

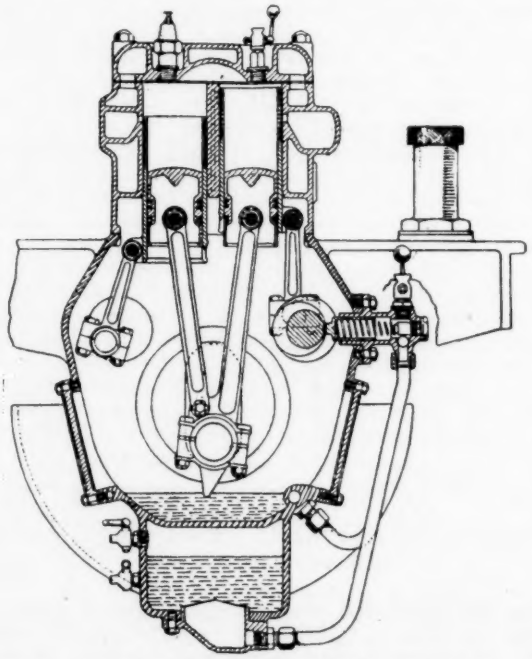


FIG. 2. DUPLEX SLEEVE VALVE MOTOR, SECTIONAL END VIEW FROM THE FRONT

this condition is that a very deep fuel bed is employed. To get away from this excessive weight the author resorted to the use of a thin belt of fuel which made it necessary to maintain two things: (1) a regular feed of fuel in small measured quantities, and (2) continuous agitation of the whole fuel bed in order that no channels or holes in the fire might occur, and that all ash might be constantly sifted out and the fuel bed kept light and porous to give easy passage to the air and water vapor through it. In the producer used by the author the depth of the furnace chamber was approximately 12

inches, the depth of fire being only 6 inches and it is stated that the producer with such a thin bed of fuel works very low, and that of anthracite, semi-anthracite and hard non-caking steam coal only dust is found in the scrubber.

The feed and grate mechanism were driven by the engine of the vehicle and a mechanical ash discharge was also added. This enabled a further reduction in the size of the producer by doing away with the necessity of providing an ash pan large enough to contain the ash formed during some hours' running.

As great flexibility in the operation of the producer was desired, it was found that water could not be fed directly to the fire which made it necessary to feed it as steam, and further in order to keep the quality of the gas constant the air passing to the producer had to be used as a regulating medium for the steam supply. A small vaporizer or boiler was therefore fitted to the producer heated by radiation through the fire and the passage of gas through a channel formed in it. (Figs. 3 and 4.)

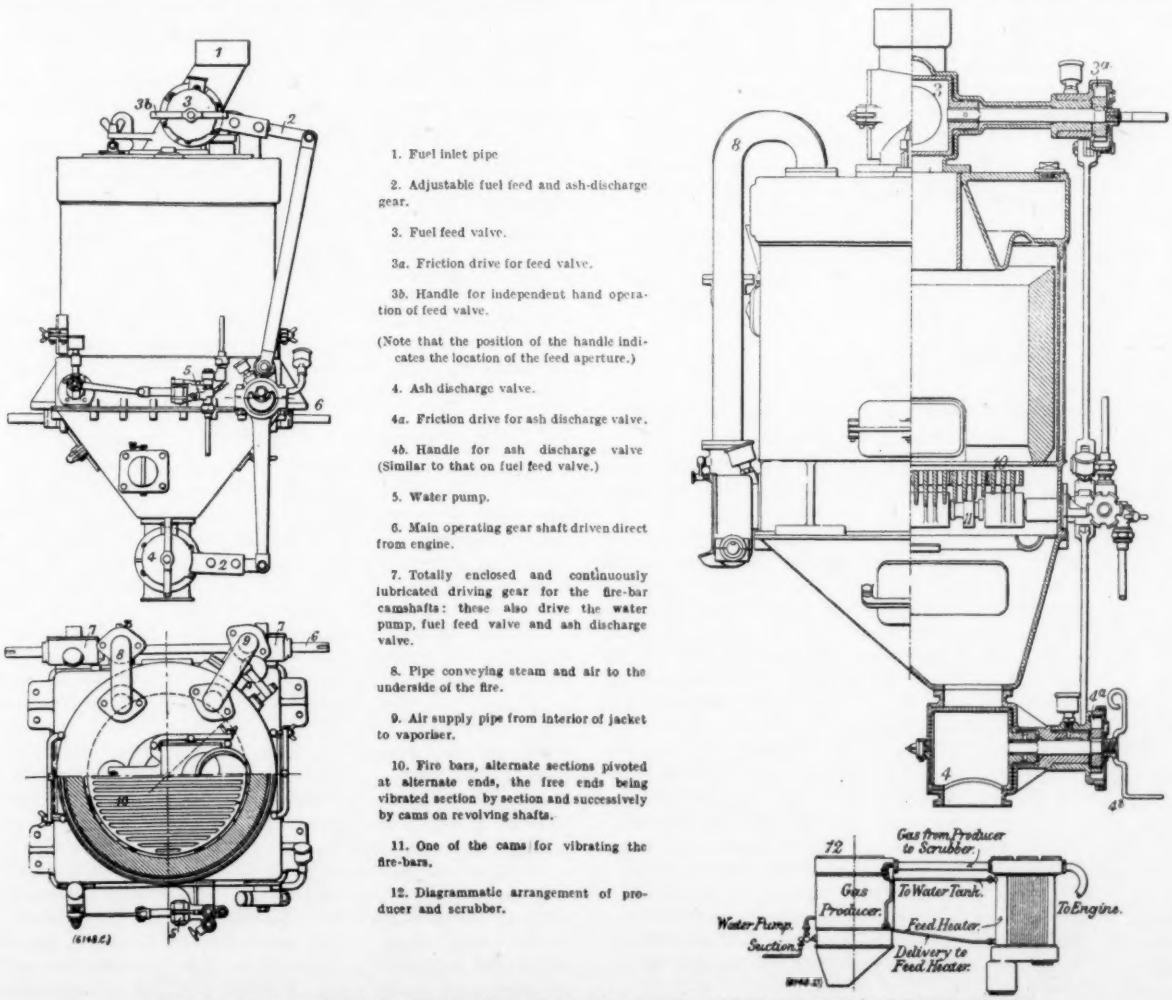
The effect of varying level in the vaporizer due to the rolling of the vehicle on uneven road was overcome by a device described in the original paper.

The producer as shown in Figs. 3 and 4 was controlled only by the speed of the engine. A throttle to the air inlet to the vaporizer was fitted, through which all air admitted to the producer had to pass. This throttle was coupled to the engine throttle, so that as the engine throttle was opened the throttle on the air inlet was partially closed. The result of this was to lower the boiling point of the water in the vaporizer, which then gave off steam freely owing to the drop in atmospheric pressure or slight vacuum to which it is subjected.

In addition to that it was, however, necessary to regulate the action of the producer also by the load on the engine which was done by means of an arrangement in which the stroke of the fuel-feed device and the stroke of the water pump were varied.

As regards the question of scrubbing the device shown in Fig. 5 is claimed to have solved the problem of making it automatic. This device is in three sections (1) the feed heater; (2) the cooling tubes: (3) the filter tubes.

The gas from the producer enters the top header at the left hand end, and passes down the internal tube of the feed heater, which at the lower end is coned, and this tends to increase the velocity of the gas. The gas then expands into a settling chamber or pot, and in doing so drops a very large percentage of dust in suspension. It then leaves the settling chamber by an annular passage and passes up and down two or more banks of cooling tubes. In these tubes and the headers more dust is deposited. Finally, the gas passes up two or more large diameter tubes, which are fitted with fine gauze filters of conical shape, and filter fitting the bore of the tube at the lower end; to this a cross handle is attached, which allows the filter to be easily withdrawn through the door in the top header. An arrangement is also provided whereby any filter can be closed off and withdrawn for cleaning without stopping the action of the producer, but this is not likely to be required for vehicle work. The gas on leaving the filters is clean enough for all practical purposes and carries



1. Fuel inlet pipe

2. Adjustable fuel feed and ash-discharge gear.

3. Fuel feed valve.

3a. Friction drive for feed valve.

3b. Handle for independent hand operation of feed valve.

(Note that the position of the handle indicates the location of the feed aperture.)

4. Ash discharge valve.

4a. Friction drive for ash discharge valve.

4b. Handle for ash discharge valve (Similar to that on fuel feed valve.)

5. Water pump.

6. Main operating gear shaft driven direct from engine.

7. Totally enclosed and continuously lubricated driving gear for the fire-bar camshafts: these also drive the water pump, fuel feed valve and ash discharge valve.

8. Pipe conveying steam and air to the underside of the fire.

9. Air supply pipe from interior of jacket to vaporiser.

10. Fire bars, alternate sections pivoted at alternate ends, the free ends being vibrated section by section and successively by cams on revolving shafts.

11. One of the cams for vibrating the fire-bars.

12. Diagrammatic arrangement of producer and scrubber.

FIGS. 3 AND 4. GENERAL ARRANGEMENT OF THE SMITH PORTABLE GAS PRODUCER PLANT

no more dust than is drawn into the air inlet of a carburetor when the roads are dusty. The cleaning of the filter is simple, and only takes two or three minutes. The doors are opened, the gauze filters withdrawn and water is poured in at the top doors and all dust washed out; the gauze filters are then shaken and replaced. The water from the feed pump on the producer enters the feed heater at the bottom opening and leaves at the top of the vaporizer. This cools the gas considerably and also recovers much valuable heat which would otherwise be lost. The combined feed heater and filter is very small and can be easily accommodated on the dashboard on the side opposite to the producer. Many other forms of filters will no doubt be possible, but the author thinks it will be difficult to evolve a design which at once meets the requirements and is of less weight and size.

The material found in the filter is merely the fuel dust,

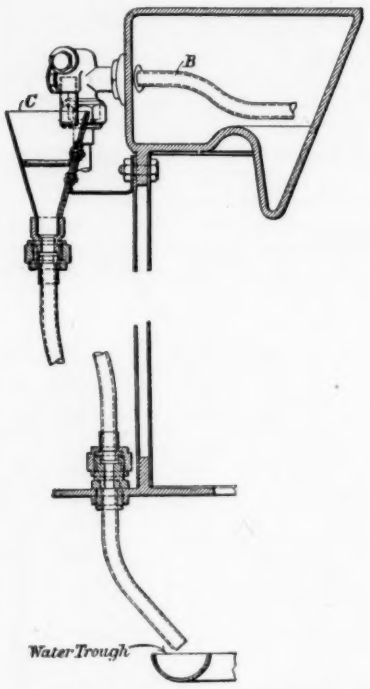


FIG. 5. SCRUBBER FOR THE SMITH GAS PRODUCER PLANT

which is quite dry and clean, and no trace of any tarry substance likely to cause trouble with the engine has ever been found.

The mixing valves and refractory lining of the producer are described in some detail. As regards the weight of the producer, it is stated that the plant which has a grate 12 inches in diameter, equivalent to 50 h.p., weighs with its connections approximately 2.75 cwt. (308 lb.), corresponding to a weight of 6 pounds per horse-power, notwithstanding the fact that cast iron was used throughout. This does not include, of course, the weight of the engine itself, but only that of the prducer and its appurtenances.

As regards the engine design, the author states that the conventional gasoline engine is entirely unsuitable for use with producer gas. With such a cheap fuel a large comparatively slow running engine could be used with approximately the same characteristics as a stationary engine. A higher compression with a half-compression device is essential, as a pressure of 120 to 150-pound gage would be necessary to obtain a fair economy with producer gas. The author recommends, for example, an engine such as the four-cylinder stationary type, 6½ inches in diameter by 7½-inch stroke, running at 600 r.p.m.

As regards fuels, the author tested anthracite, semi-anthracite, coke, charcoal, peat, maize cobs and straw, all of these fuels proving satisfactory under certain condtions.

In an editorial article on page 85 of *Engineering* for January 16, 1920, attention is called to the fact that in the paper no information is given as to the degree of reliability to be expected from the system described by J. D. Smith, a point which would be of interest to prospective users especially if they had had experience with stationary producer plants.—Paper by *D. J. Smith*, read before the Institution of Automobile Engineers, January 8, 1920, abstracted through *The Automobile Engineer*, January, 1920, pp. 22-32, and *Engineering*, January 9 and 16, 1920, pp. 59-64 and 92-95.

A PECULIAR TYPE OF INTERCRYSTALLINE BRITTLENESS OF COPPER.

WHEN copper is heated in a molten bath of sodium chloride for the purpose of cleaning and softening, it has been noticed that the copper was embrittled. Under these conditions the copper is more or less in contact with iron or steel, either from a stirring rod, forceps for handling the piece or the pot used to contain the salt, and a "galvanic couple" with the copper as cathode would be formed.

Experiments were made with small rods of copper and mild steel which were made either anode or cathode in a bath of molten salt and with an e.m.f of approximately six volts. The brittleness of the copper rods was compared with untreated material by bending the specimens back and forth with one end firmly clamped.

The copper rod which was an anode was as tough and soft as the original and required practically the same number of bends to cause it to fracture. The cathode copper was found to be very brittle.

Microscopic examination showed the anode copper to be perceptibly smoother on the surface than the original material; the structure was that of annealed copper. In the cathode copper rod the crystalline boundaries on the surface are well defined and the intercrystalline boundaries for an appreciable depth within the metal are made wider.

The probable explanation of embrittlement of the copper when it is made the cathode is that an appreciable amount of metallic sodium is formed by the electrolysis which immediately alloys with the copper, the attack being selective towards the grain boundaries rather than forming an alloy layer of uniform thickness upon the outside.—Abstract of *Technologic Paper of the Bureau of Standards*, No. 158. *Henry S. Rawdon* and *S. D. Langdon*, authors.

MECHANICAL STOKERS ABOARD SHIP.

PROGRESS of the application of mechanical stoking aboard ship. It is claimed that the introduction of oil fuel holds back their wider adoption at present. The adoption of mechanical stoker-feed aboard ship is clearly related to the introduction thereon of the water-tube boiler, and this latter is opposed in some quarters because of its alleged inferiority to the Scotch boiler in respect to reliability.

The author points out, however, that the experience of American war vessels and the vessels of the Emergency Fleet Corporation has shown that when properly handled the water-tube boiler is highly reliable and instances are given to prove this contention.

Fig. 7 shows an installation of Riley multiple retort under feed stokers such as carried out by the Erith Engineering Company of London. In this case it has been adapted to the Babcock & Wilcox-type cross-drum water-tube boiler built with tubes 14 feet long. The boilers are installed athwart ship.

Owing to the moderate continuous load very high combustion chambers are not required, the long pattern stoker operating at comparatively low combustion rates. The stoker, of course, cleans itself of ash; the coal is mechanically handled making on shipboard an installation closely similar to a modern stationary steam plant. Furthermore, the equipment does not occupy as much space as the usually installed Scotch

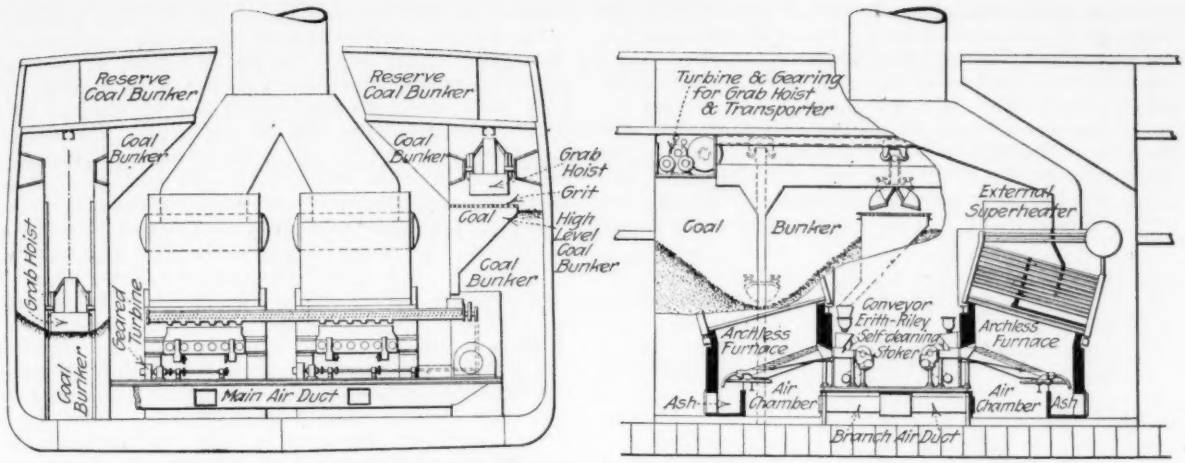


FIG. 7. RILEY MULTIPLE RETORT STOKERS AND MECHANICAL COAL HANDLING AS INSTALLED BY ERITH, OF LONDON. INSTALLED ON NEW SHIPS ONLY

boiler of equivalent steaming capacity and the weight is much less also.

The Emergency Fleet Corporation follows a somewhat different line of design, as one can see from Fig. 8. The characteristic feature of this type of installation is the baffling found by experiment with the assistance of the Bureau of Mines and claimed to enable getting the most heat out of the flue gases and into the boilers.

Here also plenty of room is provided for ash deposit and removal at the refuse end of the stokers (the coal-handling machinery is not shown).

These boilers are very much lighter for a given steaming capacity than the Scotch. The Heine boiler of 3100 sq. ft. heating surface, 225-lb. pressure, hand-fired, without grates but inclusive of water, weighs 60 tons. The Scotch of 3032 sq. ft., 220-lb. pressure, weighs dry 68.48 tons and requires 29.62 tons of water, making a total of 98 tons, as against 60 tons for the water-tube. The 8,000- to 10,000-ton ships of 11 knots speed need three such boilers. The saving in weight alone per ship is, therefore, appreciable.

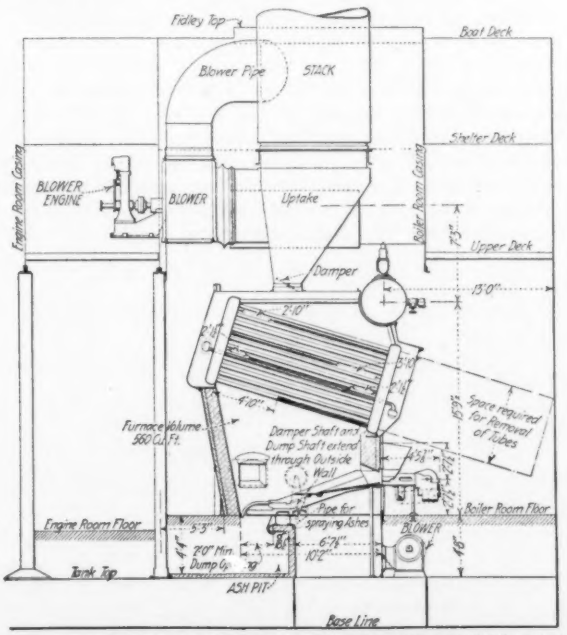


FIG. 8. GENERAL LAYOUT FOR WATER TUBE BOILER AND RILEY MULTIPLE-RETORT FOR SHIPS OF EMERGENCY FLEET CORPORATION

While the mechanics of the application of mechanical stokers aboard ship has been fully developed by the engineers of the Emergency Fleet Corporation the stokers will not be applied to the ships owing to the low price of fuel oil to the corporation. It is now somewhere in the neighborhood of 2⅛ cents a gallon, which beats coal out of running. During the war, however, the Government had to pay from 7 to 9 cents per gallon for oil and it is now believed that the present low price will not stay very long.

The navies of the world will use oil regardless of price. So, too, will fast passenger ships. It is believed by many that there is not enough oil to warrant its wide use in the merchant marine for many years, although within recent weeks rich oil finds are reported from Colombia. Just now American coal is selling in Italy for $36 a ton. The freight rate is $22. So it is not bad business now to use oil-burning ships in the coal trade to Europe. Yes, the mechanical stoker for ships is here, and when oil again becomes high-priced or its supply alarmingly diminished, it will come into its own.—*Charles H. Bromley* in *Power*, Jan. 20, 1920, pp. 86-89.

FATIGUE AND ITS EFFECT ON PRODUCTION.

A PAPER by A. Vautrin in *Technik und Wirtshaft*, published by the Verein-deutscher Ingenieure, vol. 12, No. 11, Nov., 1919, p. 748 and following, discusses in an interesting manner the nature of fatigue and its influence on productivity of labor, accidents, hours, etc.

It has been known for some time and experimentally established by Kraepelin that all work whether physical or mental done by man is accompanied by a series of reactions which either favor its continuation or oppose it.

The most important of its reactions opposing the tendency to continue working is known as fatigue and may be of physical or mental character or a combination of the two.

As regards its physical nature, it appears that all work produces in the body materials (chemical or organic) which exert gradually a narcotic effect on the central organs of the nervous system. In fact, Weichardt claims to have established in animals the presence of a poison produced by fatigue which he calls kenotoxin.

Fatigue may be either physical or mental. In physical work certain groups of muscles are in action, thereby producing a corresponding excitation in the central nervous system. Muscular fatigue takes place therefore partly on the muscular periphery and partly at the brain center and the more demand is made on the brain center the greater the final fatigue. Purely mental work creates a demand on the large brain, which means a gradual exhaustion of the gray mat-

ter and a certain demand on the nervous ganglae connected therewith. In either case, however, sooner or later there follows an exhaustion of the organs brought into action.

Moreover there is a close connection between physical and mental fatigue and it is a well-known fact that when the body is overtired for any considerable length of time, this also reduces the ability of the brain to do mental work. The reason for this is clear. All work may be physiologically considered as a process of consumption which calls into play not only the organs directly producing the work but more or less

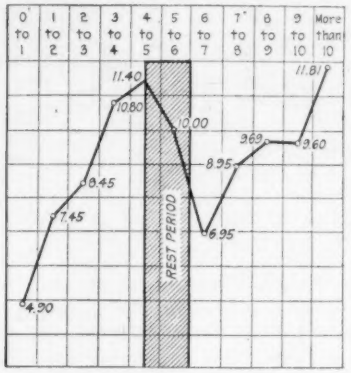


FIG. 9. DISTRIBUTION OF ACCIDENTS IN THE CHEMICAL INDUSTRY DURING THE WORKING DAYS IN THE YEARS 1897-1907

all the energy reserves of the body. Hence, bodily exhaustion will gradually lead also to mental exhaustion, and an overburdening of one part of the body by products of fatigue will nesessarily sooner or later affect the operating ability of all the other parts of the body.

Fatigue is only a moderate degree of the lowering of the producing ability of the body due to exhaustive work. A greater degree thereof is known as exhaustion and the difference between the two is stated as follows: Fatigue leads to the lowering of the ability to perform work; exhaustion repre-

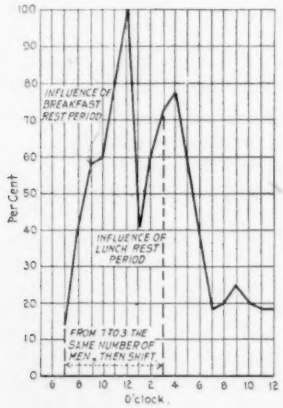

Per Cent
INFLUENCE OF BREAKFAST REST PERIOD
INFLUENCE OF LUNCH REST PERIOD
FROM 7 TO 3 THE SAME NUMBER OF MEN, THEN SHIFT
O'clock

FIG. 10. DISTRIBUTION OF ACCIDENTS IN A GERMAN CABLE FACTORY THROUGHOUT THE WORKING DAY

sents a state at which the performance of work becomes entirely impossible. Physiologically, exhaustion represents such an accumulation of the products of fatigue that the body is unable to reconstuct itself for the time being.

A clear difference must be made between fatigue, which is an objective phenomenon and represents the actual failing in the ability to perform work, and the subjective feeling of fatigue, namely, tiredness. Whereas fatigue is produced by the actual physiological processes of exchange of materials in the body, tiredness may be the result of various conditions and circumstances lying often entirely outside of the effort to produce work. Fatigue is a physiological phenomenon; tiredness psychological. It may be due to lack of interest in the work performed, outside happenings in the life of the workman, etc. These facts have been established by an investigation made by Marie Bernays on the tiredness of workmen in the Gladbach Textile Works. It was found there that it is the highest paid workmen, those which work most carefully that get tired most quickly, because the work becomes a torture to them.

The degree of tiredness depends mainly on the condition of the workman and the same amount of effort will produce a greater tiredness in a weak man than in a strong man, in a man poorly nourished than in one well nourished, in boys and women greater than in grown-up men.

The paper brings some facts in confirmation of the claim often brought out before that there is a distinct connection between fatigue and accidents. Although the author makes it clear that he does not consider accidents as being due to fatigue. From his data it would appear that in hours when the fatigue of the workman is still light there are scarcely any accidents, while in the sections of the working day or week when the fatigue has grown to an appreciable extent the number of accidents is more than double the average. Figs. 9 to 11

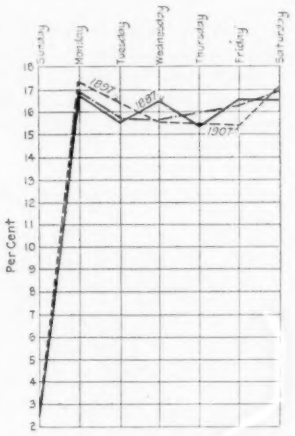


FIG. 11. FREQUENCY OF ACCIDENTS IN THE VARIOUS DAYS OF THE WEEK COMPUTED PER 100 WOUNDED OR KILLED PERSONS

together with tabular data in the article, would indicate that interruption of the working day by rest periods reduces accidents very materially and that of all the days of the week Saturday, the day when fatigue is at its climax, is also the worst day from the point of view of accident occurrence, particularly where the Saturday half holiday is not employed.

These statistics were collected in Lower Frankonia in 1895:

With a 9½-hour working day there were 1.1 accidents per 100 workmen.

With a 10½-hour working day there were 2.0 accidents per 100 workmen.

With a 13-hour working day there were 13.2 accidents per 100 workmen.

More than 13-hours there were 17.0 accidents per 100 workmen.

In printing establishments the accidents for the years 1910 to 1913 were on an average distributed in the following manner through the days of the week:

Sunday	136
Monday	535
Tuesday	583
Wednesday	530
Thursday	543
Friday	580
Saturday	585

Progress in the Field of Electricity

Summaries and Excerpts from Current Periodicals

MERCURY ARC RECTIFIERS FOR LARGE OUTPUTS.

SINCE the mercury arc rectifier entered the field of industrial application its theory, as well as its general construction, has been the subject of numerous publications. It is, therefore, hardly necessary to touch here on the principles involved. It will suffice on this occasion to recall that the "vacuum tube rectifiers" of Mr. Cooper Hewitt have been known since 1902. The current capacity of such rectifiers is limited by the maximum permissible size of the platinum leading-in wires, but nevertheless they have been successfully constructed for currents up to 100 amperes, after which an increase of capacity is only obtainable with a reduction in the life of the apparatus. Such rectifiers have been extensively used with excellent results for battery charging for the supply of small motors and arc lamps in series.

The loses in the mercury arc rectifier are equal to the product of the current and the pressure drop across the arc. The latter is independent of the current value—it varies from 13 to 20 volts according to the pressure at the terminals. Consequently the efficiency of rectifiers at high pressure is very high—for instance at 500 volts an efficiency of 95 per cent can be obtained which remains practically constant down to very light loads.

The favorable results obtainable with apparatus of low output encouraged the Société Anonyme Brown, Boveri & Company to investigate the question of building rectifiers for large outputs. A "Rectifier Company" was formed by the firm in 1912 in Glaris, Switzerland, for the purpose of carrying out the necessary experimental work. The technical staff met and overcame numerous difficulties of a practical nature. Large metallic chambers sufficiently gastight to enable the maintenance of a vacuum of 0.02 mm. of mercury were constructed. Then the insulated terminals for the conductors carrying the current to the electrode, required the invention of joints which should be perfectly gastight. Again, it was necessary to provide means for preventing short circuits between the anodes which may occur when an arc is started between two fixed electrodes. It is possible to prevent them by carefully choosing the position of the electrodes in the apparatus and by compelling the arc to follow a predetermined path with the aid of shields and suitable guides. Another danger that had to be guarded against consists in the discharges which may occur between the anodes and the neutral substances in the interior of the chamber; the latter may cause a black deposit in the rectifier and rapidly put it out of order.

Since 1915 the Brown, Boveri & Co. have been able to construct thoroughly reliable rectifiers of large output. Further improvements were made in their 1917 models. The larger units are water-cooled. The arc chamber is provided with a water jacket, while cooling water also circulates around the condensing cylinder, the cathode and the cover carrying the anodes. Further the anodes are cooled by means of ribbed cylinders (containing water) surrounding their upper extremities. In the case of rectifiers working at less than 600 volts d.c. pressure, and provided that both poles are insulated, running water from the mains may be used if it is of suitable quality. In all other cases a self-contained system is installed consisting of a radiator located in a convenient position, and a pump.

A vacuum is created in the arc chamber by means of a two-stage vacuum pump which is an essential accessory to each installation; with these pumps a vacuum of 0.005 mm. mercury is obtainable. After a rectifier has been a few months in service the mercury seals are properly formed and the cylinders are then hermetically sealed. Further operation of the vacuum pump is not required as a rule—any slight decrease of the vacuum which may be observed when the apparatus is not on load is compensated under working conditions by the absorption of the gases by the arc. The vacuum pump has been so designed that it requires no supervision during operation, and as no oil can escape from it should the pump stop accidentally, service interruptions caused by oil escaping from the pump and thus allowing air to penetrate into the rectifier are avoided. The actual degree of vacuum varies from 0.01 to 0.1 mm. of mercury, and it is sometimes found in practice that an electrical method of measuring the vacuum is preferable to the use of the McLeod vacuum gage.

As the internal construction of this class of rectifier remains practically unchanged for working pressures between 110 and 800 volts, a few standard sizes—graded in accordance with the current output—cover a wide range of requirements. Up to the present two sizes have been standardized, namely for 250 and for 500 amperes. Larger outputs have so far been dealt with by employing a suitable number of cylinders in parallel. It is said that pressure up to 2,400 volts can be dealt with. A third standard size—for 1,000 amperes and 750 volts continuous rating, is now in course of construction. The aggregate capacity of the rectifiers already supplied, or under construction in the Baden works of Brown, Boveri & Co. amounts at the present time to over 30,000 kw.—From *The Electrician* (London), Jan. 2, 1920.

THE HUMAN BODY AS A CONDUCTOR OF ELECTRICITY.

BY PROF. M. GILDEMEISTER.

THE rapid strides of the electrical industry have greatly increased the human comforts in many directions, unfortunately this has been accompanied by the loss of human life due to electrical accidents. The protective devices would become more effective if based on a thorough knowledge of the conductivity of the human body.

There is a considerable amount of material on this subject to be found in the physical, physiological and medicoclinical works. However, there has never been an attempt made to review the whole mass of these single and very often contradictory observations and measurements from a common view point. This report seems to be the first such attempt based not only on the previous experience and observations but also on a mass of original experiments.

The more important contributions on this subject are: the book by Boruttau and Mann[1] and a recent paper in "Pflüger's Archiv für die gesamte Physiologie." Measurements on living bodies can be performed only with currents of low or medium density. Current densities that result fatally can be applied only to fresh corpses. Such tests have not been conducted as yet on large or systematic scale. Therefore, the results given here are perhaps not available for practical applications without further researches. On the other hand, it seems that with an increasing current density there is observed a certain uniformity of results which allows of judicious interpolation.

Further difficulties hindering the obtaining of right values of the resistance of the human body lay in the properties of the upper layer of the human skin in the variations resulting from size and distance of the electrodes, kind of current used

[1]Boruttau and Mann. Handbuch d. ges. Med. Anwendungen d. Elektrizität. Bd. 1 Berlin, 1909.

and its duration, voltage, frequency, etc. When the problem was even reduced to its simpler form of determining the resistance from hand to hand values were obtained varying in the ratio of 1:100. On this account an opinion was advanced that the resistance of the body is very variable and that it is greatly influenced by the blood vessels of the skin, the nerve system and similar factors. In reality these factors play an unimportant part.

The variations in the resistance of the human body will be better understood if we discard the assumption that it has ohmic resistance only. It is assumed that it has also inductance or capacity, or both. The results known so far are examined from this stand point, and this report is subdivided as follows:

1. Measurement with direct current.
2. Measurements with alternating current: A. Without consideration of the phase displacement (apparent resistance). B. With compensation for the phase displacement (actual resistance).
3. Simultaneous and comparative measurements with both direct and alternating currents.
4. Discussion of electrostatic or polarization capacity.
5. Theoretical considerations.
6. Data and constants.
7. Conclusions.

Measurements with direct current show that during the first few thousandths of a second (with constant current and

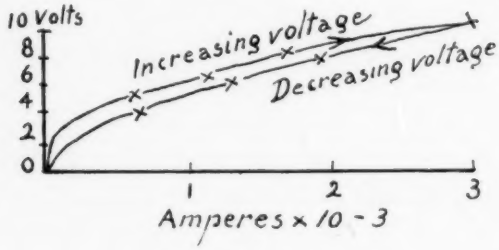


FIG. 1

voltage) the resistance is very low, the oscillograms taken showing a sharp current peak, on recovering its high initial value, the resistance then gradually decreases with time and after a certain period reaches a permanent value. With a pressure of 10 volts this more or less permanent value was reached after a period of 115 seconds. The resistance is also decreased with increase of voltage, a hysteresis effect being noticeable when the voltage is changed from higher to lower values and vice versa. This is clearly shown in Fig. 1.

With alternating currents there is observed a phase displacement with a leading current. The apparent resistance of the body decreases with time but not quite as much as the case is with direct current. Tests performed by Dr. Rasehorn of Siemen's and Halske show that with increase of voltage the apparent resistance decreases considerably, while the higher the frequency the lower is the apparent resistance.

However, when the phase displacement is compensated by a seld-induction according to the method of M. Wien[a] then the true resistance is, as shown by researches the results of which have not been made public as yet, quite constant with time, slightly increases with increase of voltage and greatly decreases with increase of frequency.

These phenomena could be explained by the theory of electrostatic capacity, the skin acting as a dielectric. However the experimental work seems to disprove this hypothesis and confirm a new theory, namely that of polarization of the skin. According to the physiologists our skin cells are covered with semi-transmitting membranes which let water through but not the electrolytes filling our body. When such a membrane is traversed by a current the electrolyte adjacent to it is concentrated forming a concentration cell the pressure of which is opposed to the impressed voltage. The mechanism of polarization is thus the same as that of reversible metal electrodes.

The delicate membranes are now disturbed when in contact with an electrolyte of unusual degree of concentration, and if this condition lasts over a certain length of time the membranes suffer a deterioration and allow the electrolyte to filter through. This results in the decrease of the concentration difference and of the E. M. F. of polarization. With the breaking of the current the membranes seem to be able to recover their original properties. This polarization theory explains not only the variations of the resistance of the body with the kind of current, voltage and frequency but also its variations with time element and the hysteresis effect.

In view of the above theory the E. M. F. of polarization plays but a little part when the impressed voltages are high, as is usually the case in electrical accidents. It follows that the true resistance is that obtained by high frequency measurements. In case the skin is dry, there is an electrostatic capacity in addition to the polarization capacity. Then the body may be said to consist of two polarization cells in series, of a resistance between them, and of a very small condenser parallel to the whole circuit. It was also observed that in certain cases the polarization capacity of the skin forms, together with a self-induction, a system capable of oscillations and gives rise to resonance phenomena. These researches have not been completed.—Investigation made by the Physics Department of the Physiological Institute of Berlin. *Elektrotechnische Zeitschrift*, September 18, 1919, pp. 463-66.

[a] Annalen der Physik, v. 58, p. 37 (1896).

DAYLIGHT SAVING.

Historic Note.—In accepting the invitation of the Lighting and Illumination Committee to present a paper on "Daylight Saving" the author stipulated that a considerable part of the paper would have to be devoted to matters remote from electrical engineering, the economic and sociological aspects of daylight saving surpassing in importance the effect upon the use of artificial light.

Benjamin Franklin is considered to be the father of daylight saving. In modern times William Willett was sponsor in England for a proposal to advance the clock in summer time in order to utilize daylight to better advantage. On May 1, 1916, Germany as a war measure adopted the plan by advancing clocks one hour for the summer period, England, France and several other countries took like action within the next few months.

On this continent the experiment of advancing the clock had been tried in several localities with varying success. It was adopted in Cleveland in the spring of 1914. In Detroit which lies just within the boundary of the central zone the clocks were advanced on May 15, 1915, bringing the city into conformity with normal eastern time both in summer and winter.

After considerable agitation by the National Daylight Saving Association, the U. S. Chamber of Commerce and other bodies a bill passed both houses of Congress and was approved March 1918, fixing standard time to govern the movement of common carriers engaged in interstate commerce and other activities under Federal jurisdiction, and providing for the advancement of such standard time by one hour during the period between the last Sunday in March and the last Sunday in October. The states of New York and Pennsylvania adopted parallel legislation to govern state activities. The Federal Act remained in force for two years, but that provision which called for advanced time during the summer months was repealed in August, 1919.

In European countries such as England, France and Germany, the daylight saving plan will probably be followed

during the coming summer as in the recent past. In Canada, after a trial during 1918, proposed renewal of the daylight saving bill was defeated in the Dominion Parliament in 1919. It is understood also that in Australia after a trial daylight saving has been abandoned.

Since the repeal of the Federal Daylight Saving Act in this country the subject has been agitated locally in several cities. For example, in Cincinnati advanced time has been adopted to be effective during the entire year, thus conforming to the action of Cleveland and Detroit. In New York, Hartford, Philadelphia, Pittsburgh and other cities provision has been made for advanced time in municipal activities during either five or seven summer months. In Chicago after consideration it has been decided to adhere to normal Federal time. After a year's experience in England a Parliamentary Committee conducted an investigation of the daylight saving and reported in favor of its continuance. In the United States there has been no organized investigation of its operation.

ADVANTAGES AND DISADVANTAGES.

Reduced Use of Electricity and Gas.—A considerable amount of statistical data were examined. It appears that daylight saving reduces the total output of certain central stations and of one gas company by about three per cent during the seven summer months. A reduction in output for lighting alone is found to average 8 per cent. Applying these fragmentary data to the country as a whole there is estimated an annual saving by the public of $19,250,000 in expenditure for artificial light and a reduction of about 495,000 tons per annum in consumption of coal.

Other advantages of daylight saving are: Outdoor recreations and gardening. Gardening by those however who produce a surplus for sale has been impeded by the Daylight Saving Act. Upon the whole the evidence appears to be that the disadvantages to professional gardeners of daylght saving have outweighed the advantages to amateur gardeners. It is probable that real improvement has accrued to certain classes of urban and suburban dwellers.

There seems to be practically a consensus that advancement of the clocks in summer brings bedtimes for small children well into daylight and interferes with their sleep. Thus children either sit up later or after retiring remain awake longer by the clock than formerly.

As to the city tenement dwellers it may be stated that from all observations the daylight saving brings them only disadvantages during the summer months.

Disadvantages are experienced principally by farmers and dairymen. The crux of the difficulty is that much of the work in the country must be regulated by the sun. United States Senator Capper of Kansas estimates that daylight saving occasions wastes aggregating $1,000,000,000 a year. While definite figures are not available it is probable that economic losses probably far outweigh the gains.

Custom in allocating hours for work, sleep and play has been evolved through experience. It is undesirable to alter it by arbitrary legislation. It is important to "think nationally." To secure the greatest advantage to the whole people should be the aim. The very obvious solution of the problem appears to lie in diversification of hours of industry. There are certain classes of people in the cities and suburbs who are in position to derive benefit from advanced summer time. Without molesting the customs of an entire nation let them undertake an educational propaganda in favor of early rising and early retiring in summer time, together with advancement of the beginning of business hours from say 9 to 8 A. M. It will probably follow that where the advantages of such altered practice seem sufficient, business hours in certain kinds of work will be advanced with consequent diversification of the traction peak, bringing greater comfort to those who must travel in the rush hour. This will avoid local misadjustment of clocks with the attendant confusion which will arise from difference between Federal and local time.—Paper presented by *Preston S. Millar* at the 8th Mid-winter Convention of the A. I. E. E., New York, February 18, 1920. (*Journal of the American Institute of Electrical Engineers*, February, 1920, p. 146-158.)

ELECTRICAL EXPORTS IN 1919.

ELECTRICAL exports for the calendar year 1919 amounted to $89,089,711, which surpasses in value the exports of any previous calendar year. Especially heavy foreign sales were made in batteries, generators, insulated wire and cable, metal-filament lamps and motors, while miscellaneous material increased almost ten million dollars.

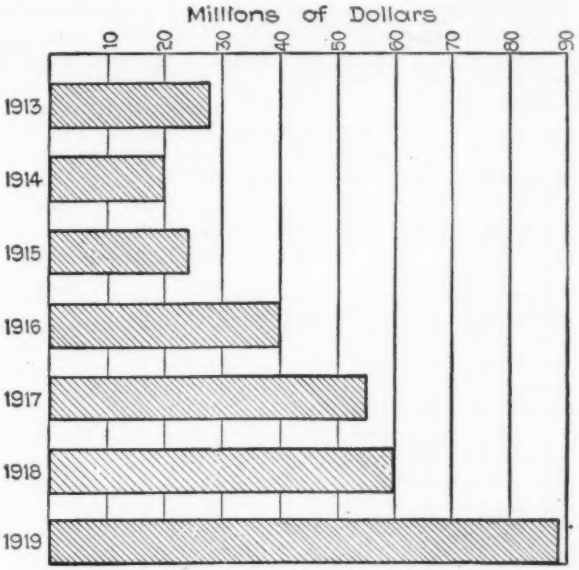


FIG. 2. SEVEN YEARS OF ELECTRICAL EXPORTS

This increase above 1918 of approximately 50 per cent in value of exports is not due entirely to increased volume of goods shipped; some of it is due to the higher prices which have been obtained during the year.

Because of unfavorable rates of exchange it is expected that exports during 1920 will not equal those of 1919. Of the four main foreign outlets—Canada, South America, Europe and Asia—the exchange rates of Asia (excepting Russian territory) and of South America are rather favorable, while those of Canada and Europe are unfavorable. Consequently it would not be surprising to find that Canada during 1920 had to recede from its present position as the single largest outlet for the United States manufacturers. At the same time the tendency is for domestic manufacturers to open branch factories in Canada, and this will lessen the amount of money that country will spend for foreign apparatus.

The accompanying chart shows the growth of our electrical exports for the last seven years.—From *Electrical World*, Feb. 7, 1920.

ELECTRIFICATION OF THE DRAMMEN RAILWAY.

THE contract for electrifying the section Christiana-Drammen has been awarded to a Norwegian amalgamation concern headed by A/S Per Kure. Work was commenced last summer, and the electric conductors are at site. The foundations for the masts will be constructed in concrete next spring, while the remainder of the material, including the masts, is being manufactured in a number of factories in Norway and Sweden. The section Christiania-Asker is to be finished by the end of 1920, and the remaining part of the section by the close of 1921.—*Teknisk Ukeblad*, Dec. 5, 1919. Abstracted by *The Technical Review*.

Progress in Mining and Metallurgy

A Summary of Important Articles

Prepared Under the Auspices of the American Institute of Mining and Metallurgical Engineers

A NEW OCCURRENCE OF PRO-EUTECTOID FERRITE.

By Charles Y. Clayton.

Cast-steel runners, while not interesting from a commercial standpoint, furnish valuable material for microscopic study. Foley found not only the usual ingot structure, but zones of Widmannstättian structure, which he explains as due to differential crystallization. The writer, in examining nickel-steel runners, found a type of pro-eutectoid ferrite that is unusual and most probably new.

The runner in question was 8.75 cm. (3.5 in.) in diameter and analyzed at its center 2.69 per cent nickel and 0.350 per cent carbon and at its edge 2.62 per cent nickel and 0.359 per cent carbon. The macro-structure, which is the usual type, is shown in cross-section and the longitudinal surface, respectively. Slight segregation of ferrite can be seen near the center of the segment and at other points near the edges of polyhedral grains.

Stead's reagent brings out the dendritic structure within the grains. This texture is what would be expected of such a steel. Other figures show the peculiar swirls of pro-eutectoid ferrite, the finding of which prompted this paper. These swirls, or eddies, if such a term can be applied, occur in all parts of the runner and in all parts of the individual grains.

A possible explanation of these swirls of ferite is that the whirling motion of the molten steel in the runner causes the tips of the dendrites and dendrite branches to be rounded at different periods of crystallization due to resolution. Upon these rounded points, low-carbon autenite would be precipitated, due to selective freezing or the differential crystallization of Foley. Non-ferrous matter would, as a result, have a similar arrangement due to its stratigraphic history. Upon passage through transformation range, the arrangement of the pro-eutectoid element would be dependent on the previous distribution of the ferrous and non-ferrrous elements. Two cast nickel-steel runners from different heats exhibited this same peculiar occurrence of the pro-eutectoid element.—Abstract of paper to be presented at Lake Superior Meeting of American Institute of Mining and Metallurgical Engineers, August, 1920. From *Mining and Metallurgy*, March, 1920.

INDUSTRIAL REPRESENTATION IN THE STANDARD OIL COMPANY.

By Clarence J. Hicks.

The labor policy of the Standard Oil Co. (New Jersey) is founded on paying at least the prevailing scale of wages in the community; on the eight-hour day, with time and one-half for overtime; one day's rest in seven; sanitary and up-to-date working conditions; just treatment assured each employee; payment of accident benefits beyond the amount prescribed by the State compensation law; health supervision by a competent medical staff; payment of sickness benefits after one year's service; coöperation with employee in promoting thrift and better social and housing conditions; and assurance for a generous annuity at the age of 65, guaranteed for life after 20 years of service. Most of these features have been a part of the company's policy for many years, but it is only during the past two years that the coöperation of employees in determining these matters has been definitely assured through industrial representation.

Industrial representation, in the Standard Oil Co., is a principle rather than a procedure. Representatives of employees and representatives of management evolved a simple plan, the basis of which is that it gives every individual employee representation at joint conferences on problems and fundamental principles affecting all those interested in the industry. Experience has definitely shown that representatives of the employees are not only alert for the employees' interests but are as keen as the representatives of the management in determining and insisting upon fairness to the employer.

The plan was brought into operation by an invitation to employees to coöperate in maintaining the company's policy.

The joint works (or plant) conferences are held at regular intervals to consider all questions relating to wages, hours of employment, working conditions, and any other matters of mutual interest that have not been satisfactorily settled in the joint division conferences. These joint division conferences meet whenever needed to discuss and adjust matters within the smaller confines of a division. Many problems never go beyond the joint division conference, unless the problem develops into one that concerns other divisions. In case any matters are to come up on which the joint works conference could not agree, they would be referred to the Board of Directors for final decision. But as yet not a single case has been referred in this manner.—Abstract of a paper to be presented at Lake Superior Meeting of American Institute of Mining and Metallurgical Engineers, August, 1920. From *Mining and Metallurgy*, March, 1920.

OIL POSSIBILITIES IN NORTHERN ALABAMA.

By Douglas R. Semmes.

The possible oil territory of Alabama can be readily divided into two regions, the Paleoöic area of the north, and the Coastal Plain province of Cretaceous and younger formations lying to the south. This latter area has received much attention in the last few years and has been described by a number of writers. Although the possibilities of the Cretaceous series have been much emphasized by recent writers, the fact remains that the two or, possibly, three localities where oil or gas have been found in anything like paying quantities are confined to the area of Carboniferous rocks. Moreover, almost all of the oil seeps and a good percentage of the gas seeps are confined to this area.

Topographically, as well as structurally, the Paleozoic area can be divided into three rather well defined provinces: (1) the broad, open Coosa Valley lying adjacent to the crystalline oldland, with comparatively little relief, except for occasional longitudinal ridges and rather intense folding; (2) the plateau region of horizontal or gently warped Pennsylvania strata broken by occasional anticlinal valleys alined northeast and southwest, outliers of the Coosa Valley proper, in which the older paleozoic formations are exposed—a region of much relief (200 to 300 ft.) and thorough dissection, well wooded, and of little agricultural importance; and (3) the Tennessee Valley region of horizontal or gently warped Pennsylvanian and Mississippian strata, where the relief is not so marked, the wooded area is less extensive, and the country is of more importance agriculturally.

OIL AND GAS HORIZONS.

The possible oil and gas horizons thoughout the section are rather numerous; many of these horizons have, locally, given very promising shows. Owing to the striking lateral variations in lithologic character, horizons that may at one point be promising have little or no possibilities at another; this is especially true in the Carboniferous series.

FUTURE PROSPECTING.

The area the writer considers most favorable for future testing is the northwestern portion of the state, where the Trenton limestone would be the producing horizon. Even this area is not without its disadvantages. The degree of metamorphism increases not only near areas of deformation but in depth in any locality. Therefore the degree of metamorphism of the Ordovician formations, once covered to great depth by the Pennsylvanian series, may be much greater than is indicated by the Pennsylvanian coals, in which case commercial accumulations would be improbable. Moreover, there is a possibility of an unconformity below the Silurian. Nevertheless, considering the structure, the lithologic character of the section, and the evidence of the carbon ratios of the overlying Pennsylvanian coals, the area is undoubtedly worthy of further tests, provided they be well located on carefully determined structure. In addition to this area, the Coal Measures, where exposed in Winston, Marion, and Fayette Counties, should be well worth testing, especially where drilling is continued to sufficient depths to test the Hartselle and the Trenton horizons.—Abstract of paper to be presented at Lake Superior Meeting of American Institute of Mining and Metallurgical Engineers, August, 1920. From *Mining and Metallurgy*, March, 1920.

Progress in the Field of Applied Chemistry

Notes Culled from Current Technical Literature

PAPER FROM BAGASSE.

WHILE much has appeared heretofore upon the possibility of producing various grades of paper from bagasse, as the sugar cane from which the juice has been expressed is termed, these considerations have been based on experimental results and discussion of the possibilities based on these trials. *The Tech Engineering News* in its first issue, February, 1920, contains a description of the first commercial sized mill which has been put into operation in making a special paper from bagasse. The present method of operation is of course based upon experimental runs made in this country before the mill was built in Hawaii.

The article points out that failure in the past has been caused in part by the low yields of pulp obtainable from bagasse, and partly because the pulp has heretofore been converted into a quality of paper to which it was not well adapted. The further point is made that the manufacture of paper involves two distinct operations—the first being the production of pulp principally by chemical methods, and the second the mechanical operation of converting this pulp into paper. The pulp processes are, roughly speaking, either acid or alkaline in their nature, and the article in question gives a brief description of these typical processes. Either the soda or the sulphate process may be applied to the cooking of bagasse, which must first be separated by shredding and screening methods into pulp-making fiber and non-fibrous pith which is detrimental in paper making. The fiber is suited for the preparation of book or writing papers and the pulp is expected to find its greatest application in mixtures with rag, sulphate or soda fibers. The most suitable composition of the liquor in which the bagasse is to be cooked by the sulphate process is stated to consist of 15 per cent caustic soda and 7½ per cent sodium sulphite. About three parts of cooking liquor to one of the bone-dry fiber gives the most satisfactory yield. The time of cooking is five hours at 100 pounds pressure, or eight hours at 75 pounds pressure. If, however, the soda process is employed, a liquor with twenty-five per cent caustic soda is used for a period of five hours at a pressure of 100 pounds.

The primary product of the mill in question is a peculiar sort of paper made to meet the specifications of the Eckart process, which requires that the paper shall, when asphalted, withstand five or six weeks of weather, and at the same time be sufficiently soft and weak to allow the sharp growing points of the sugar cane to penetrate it. The apparent success of the Eckart process in the cultivation of cane has been the subject of much discussion, since experiments on large areas have indicated that the cost of growing the cane may be reduced from 50 to 70 per cent and the crop increased by ten tons per acre, equivalent to one ton of raw sugar. This simple method of weed elimination is of great economic importance, since the statement is made that in one district alone one million dollars has been spent annually for cultivation.

The paper, staked upon the fields over the cane rows, also serves to create a condition which causes more rapid and vigorous growth of the cane, as well as the sprouting of all weed seeds at a time when they are quickly blanched and withered beneath the black paper.

This grade of bagasse paper is prepared by cooking the bagasse for twelve hours with lime under sixty pounds pressure, after which the pulp is allowed to remain in storage for a few days, is then run out on the paper machine and afterwards treated with asphalt. The article in question is illustrated, including one view of a cane field four weeks after the paper has been spread over the cane rows. In this case the paper is held in place by cane field litter.

A NEW PLAN FOR RESEARCH CO-OPERATION.

IN the January 10 issue of *Chemical Age* there is given an outline of a new plan for coöperation in research between one of our large technological schools—the Massachusetts Institute of Technology—and the industries. The plan is based upon the principle of reciprocity in which the point is made that the nation's strength lies in its industries and the industries in turn depend upon the technical schools for the most important element in their organization, namely trained men. The Institute in effect takes the stand that if the constant demand for suitably trained men is to be met and the Institute is to furnish its quota, it must have additional funds, and it is therefore proper for the industries who are to gain the most from the efforts of these men to supply the necessary resources. These funds have been secured by means of 153 contracts, totalling $1,810,875, and this sum is considered as retainer fees in return for which the Institute agrees to permit the corporations retaining her to consult the members of the staff and faculty on problems pertaining immediately to the business of the company; to use to the greatest possible extent the library, the files, and the facilities of the Institute, and to place records of the qualifications, experience and special training of the alumni at the disposal of these industries in an effort to assist them to strengthen their own organization. The Institute also undertakes to supply information as to sources of special knowledge in any given subject and to give these industries the first opportunities to secure the services of Technology graduates.

So far as is known, the plan thus briefly outlined is unique. Members of the faculty of educational institutions have frequently been retained as consultants by commercial interests, and manufacturers have always been encouraged to maintain

scholarships in science, preferably without restrictions, but sometimes upon special phases of science in which the donor has been interested. Another plan, having for its purpose the training of men while problems were in the course of solution, has been very successful as developed at the Mellon Institute. In the latter instance, the work has been conducted for the benefit of the donor of the fellowship, who has had exclusive use of the results for a limited time, and the men especially employed for any given problem have frequently gone into the industry. The Massachusetts Institute of Technology before the war put into practice another unique plan for the training of men which, under the name of the School of Chemical Engineering Practice, devised a plan whereby properly qualified students could be sent in groups for limited periods to stations chosen with reference to demonstrating the typical unit processes employed in chemical manufacturing operations.

To have an educational institution become a general consultant is an experiment which will be watched with great interest and the plan may conceivably go far beyond its original scope. The article mentioned ventures the opinion that ultimately the Institute may become the greatest consulting body in the country, and it would follow that since the great corporations of the country have retained the school as a consultant, the great experts of the country would ultimately be members of its instructing staff. It is also suggested that industry will ultimately go to Technology instead of having the instructing staff and students go to the industry, as is frequently done at present. It is not quite clear by what means the Institute will be able to attract and hold the country's greatest consultants, and the range of possible problems presented by 153 manufacturing establishments will undoubtedly require a diversity of talent for their solution which has heretofore seldom, if ever, been found in a single establishment.

The Division of Industrial Coöperation and Research is the designation of the new department of the Institute responsible for the successful execution of the new contracts.

A NEW FACTOR IN TEXTILES.

THE Textile Industrial Institute has been established for a number of years at Spartanburg, South Carolina, where a favorable arrangement with a nearby cotton mill has made it possible for students to work their way through school and become better fitted to occupy positions of responsibility in the cotton industry. Students have worked in pairs, spending alternate weeks in the mill and in the class room, putting into practice one week what had been learned the preceding. This plan kept a constant number in the mill and in the school.

The usefulness of the Institute is now being greatly extended through the erection of a model cotton mill, which its designers have tried to make the last word in design, construction, and equipment. The plant which has cost something more than $200,000, has been provided by the coöperative contributions of more than eighty cotton mills in the Carolinas and Georgia and an equal number of equipment manufacturers.

In this mill, which will be operated by the more advanced students of the Institute, raw cotton can be taken in and carried through every step to goods mercerized, singed, dyed but not printed, and finished for market. For example, there are eighteen kinds of looms in this model mill and cotton can be treated by any of the methods known in spinning, twisting, weaving, etc.

The importance of the plant becomes more evident when it is realized that heretofore the planter who has grown some new strain of cotton or for any reason is interested in knowing just what valuable characteristics a small portion of his crop has, has been unable to have complete trials made under manufacturing conditions. It has been difficult therefore to interest progressive planters in growing comparatively small trial crops, and manufacturers have doubtless suffered through the lack of information not to be gained otherwise. At the present time the mill is running on an entirely new kind of cotton from which great things are expected.

The school will be able to finance the operation of the mill by the sale of their products for which they have an accredited list of more than 11,000 customers very widely distributed geographically.

A CENSUS OF BLOOD CORPUSCLES.

IT has now been some time since methods were devised for calculating the approximate number of both red and white corpuscles in the blood, and the present-day diagnosis of many diseases is based upon this census of corpuscles. Refinements which mean greater accuracy depend upon staining the white blood corpuscles by methods which differentiate them in a way which enables the diagnostician to reach his conclusion with greater certainty.

The counting of blood corpuscles depends upon a glass cell one-tenth of a millimeter in depth, having one of its sides ruled into squares and rectangles. A very small quantity, say one cubic millimeter, of blood is drawn into a pipette provided with a mixing chamber in which a dilution of one to ten is made if white blood corpuscles are to be counted and one to a hundred if red ones are to be enumerated. Various diluting fluids and stains are used, and after thorough mixing, a drop of the corpuscle suspension is placed in the chamber, a cover glass applied, and the average obtained by counting a considerable number of squares and the necessary calculations made.

It will be obvious that errors cannot be avoided in dealing with such small quantities where dilution and a number of factors are used in reaching the total by multiplication. Accuracy in apparatus therefore becomes essential.

Previous to the war the finest haemacytometers were imported and soon after the great need for these pieces of apparatus for the American Army became manifest, the interest of Mr. Levy, well-known as the producer of accurate screens for photographic engravings, was aroused in the possibility of contributing to the winning of the war in this manner. Mr. Levy was interested only in case he could so greatly improve the haemacytometer that no one would be tempted to try further improvements for a number of years, and the results he obtained would seem to fit those specifications.

This haemacytometer is now made exclusively in America, and is far more accurate than those formerly imported. For example, cementing the engraved or photographic counting chamber upon the slide has been eliminated so that accuracy in the depth of the cell can be secured for the first time. By devising a parallel form of cell in place of the earlier circular ones, the effect of atmospheric pressure has been eliminated, and this was a source of considerable error in the circular chambers. In the new form a more even distribution of the corpuscles over the ruled area can be obtained, and of course the parallel form of cell is much easier to clean. By a clever use of glass of different refractive indices, the visibility of the ruling has been greatly increased in chambers filled with solution.

No one examining this American standard haemacytometer under the microscope can fail to recognize the skill displayed in etching these rulings. In one type the central square millimeter is divided into one-four-hundredth square millimeter areas, with an extra line in every fifth square for convenience in counting red corpuscles. The eight surrounding square millimeters are each divided into sixteen small squares for accuracy and convenience in counting the white corpuscles. Notwithstanding the necessity of working within such narrow limits, the intersections of these rulings are perfect and the manner in which all the lines are cut never fails to provoke admiration.

In determining the limits within which these counting chambers should be manufactured, a great many of those in use were examined, and errors amounting to as much as sixteen per cent were found in the depth of the chambers. This is

obviously so great as to invalidate the count in many instances, and it was to eliminate this possible source of error that the new construction above mentioned was devised. Thanks to coöperation on the part of the Bureau of Standards, tolerations have now been established and haemacytometers may be obtained with certificates indicating the maximum errors in the dimensions of the ruled spaces and in the depth of the chamber. Equal attention has been paid to the necessary cover glasses, so that all in all we may count the American standard haemacytometer among those results of the war which will prove of permanent benefit.

PROBLEMS IN ALLOYS.

IN considering the possibility for coöperative research upon alloys, the Divisions of Research Extension and of Engineering of the National Research Council have obtained suggestions from a number of leading metallurgists concerning those problems involving fundamental research which might be taken up with a certain profit to those both using and producing alloys. Among these problems, the following may be mentioned as indicating the scope of the field and the opportunities which it presents.

There is need for further work on corrosion, including the action of commercial acids and other solutions used in industry, as well as that of the atmosphere, sea water, and other substances commonly considered in such studies. This has a bearing upon such articles as conduits, containers, lead for suphuric acid chambers, roofing, and boiler tubing. We cannot expect as rapid advance as is desirable in new alloys until more is known concerning the physical and chemical properties of both pure metals and their alloys. Closely related with this is the effect of traces or small percentages of elements usually regarded as impurities upon the properties of metals. Another phase might be designated as comparative metal technology, which would include a careful comparison of mechanical properties, as well as of general physical and chemical characteristics. The desirability of a study of deoxidizers and fluxes to be used in the preparation of non-ferrous metals is obvious, and there has long been needed a satisfactory test for machinability. Other needed tests are those which can be applied without destroying the article to be tested, as for example, the magnetic tests for the location of imperfections which are now being studied by a Committee of the Division of Engineering.

In tempering work with steel we need a comparative study of water quenching and oil quenching. What is the influence of forging methods on the fibre of metals, for we often find material of the correct composition which fails after having been subjected to forging? The relative effects and the life of different bearing metals should be determined, as well as the effect of inclusions in causing decarbonized streaks in laminated structures.

Throughout metallurgical operations a closer study of temperatures might prove advantageous, especially in the case of pouring. This brings up the question of molding sands and core sands, which still need to be studied in a comprehensive way. There is a vast amount of work to be done in completing the pubished data on standard alloys, in which should be tabulated their uses, composition, tolerance in composition, physical properties, their variance with differences in composition and with impurities. There should be a similar listing and testing of the non-standard alloys for the purpose of determining whether they may not be made standards themselves or acceptable substitutes for present standards, as prices change.

The subject of heat treatment naturally comes to the forefront and it would be desirable to develop an iron as noncorrosive as the present high silicon irons but with a more satisfactory degree of machinability. The composition of dies with reference to the service they must give in die-casting with present and new alloys should be undertaken. The malleable iron field presents its own peculiar group of problems, among which may be mentioned the development of a test which would truly indicate the malleable and shock-resisting qualities of malleable cast iron.

Perhaps the most pressing need is the thorough, indexing, abstracting, and classification of all published information on pure metals and alloys. This work would bring out the state of the art, from which would be brought to light groups of new problems, experiments upon which further work is required, and lines along which new effort could be directed for the purpose of checking conflicting evidence and repeating any necessary experiments. The information obtained would form an excellent basis for monographs on many classes of metals, such as the preparation of alloy steels at ordinary temperatures with various heat treatments, and at temperatures exceeding those found under normal atmospheric conditions.

This is but an incomplete list of the problems that have been suggested and from the entire list a few will be chosen for immediate work as a program upon which to solicit the support of the industries to be benefited. As in all research work, the solution of a problem at once suggests a number of others which would not have come into view excepting through the work accomplished.

HOME-MADE SYRUP FROM SUGAR BEETS.

GROWING out of the efforts that have been made to utilize home-grown sugar beets as a source of culinary and table syrup, has come research to determine the substances which cause the undesirable flavor noted by some authors, in the hope that ways could be found to eliminate them. In the February number of the *Journal of Industrial and Engineering Chemistry*, Messrs. Ort and Withrow report their findings in an investigation, the object of which was to remove the undesirable flavor without injuring the sugar. Obviously the separation of the sugar as such would be out of the question, either in the kitchen or on the farm, and so was not considered.

In the article mention is made of the opinion held by many beet sugar men that the simple concentration of beet juice is sure to produce a syrup of objectionable flavor and odor, and that notwithstanding the work carried on intermittently during the last fifty years, none of the processes proposed has been of any value in improving these simple syrups. The directions given by the U. S. Department of Agriculture for the preparation of home-made syrups from beets do not result in very satisfactory materials according to the reports of many farmers, and in those cases the improper topping of the beets was described as the cause of the difficulty.

The authors describe their experimental work upon beets grown in Ohio in which a great many attempts were made to eliminate or destroy the undesirable flavor. These include clarification with milk, previous desiccation to coagulate the albumen, treatment with lime, peeling, coreing and treatment with such materials as fuller's earth, tannic acid, bleaching powder, and bone black. Variations of the temperature of extraction were also tried and in the end it was found that the best results could be obtained from beets from which the green shoulders, representing the portions which had protruded above the ground, had been removed by peeling. While this point was not definitely settled, it was found that syrup made from these green portions possessed the undesirable flavor to a very great degree and was quite dark in color, whereas a good syrup with but a trace of beet flavor and sometimes with no such flavor, could be obtained from beets prepared in the manner described.

The conclusions which will interest those who may be considering growing some sugar beets for their own use the coming season are summed up as follows: "The various published processes for making palatable sugar beet syrup do not consistently fulfill all claims made for them.

"The use of copper kettles is undesirable since it gives a metallic taste to the syrup. Enamel and aluminum ware are satisfactory.

"The process of skimming will not in itself eliminate the objectionable beet flavor.

"The peculiar flavor can be practically eliminated from sugar beet syrup by a proper attention to topping, paring off green portions, and brief preliminary extraction. The entire absence of green portions is necessary to good flavor.

"The objectionable beet flavor may be due partly to immaturity. Preliminary storage of beets will improve the flavor."

The chemical compounds which are responsible for the objectionable flavor have not been definitely identified.

PROCESS FOR SEPARATING LEAD SULPHIDE FROM MIXED ORES.

THE Bulletin of the Canadian Mining Institute states that the Elmore process for the extraction and separaton of lead sulphide from such mixed ores as occur in the Burma mines is based upon the following:

"When a mixtures of lead and zinc sulphides is treated with concentrated sulphuric acid at 100° C. under proper conditions as regards fineness, proportion, time of contact, etc., the lead sulphide is converted into sulphate, while the zinc sulphide remains practically unaffected. If the product is then washed in hot strong brine, the lead sulphate is dissolved and can then be separated from the undissolved zinc sulphide by filtration, etc. By cooling the hot brine, the lead sulphate is precipitated except for the amount that the cool brine will keep in solution, and the brine can then be reheated and used again. The details of course vary for different ores and there are other methods for handling sulphur dioxide, sulphonated hydrogen, or free sulphur liberated during the treatment."

LEAD PENCILS.

THE announcement that the western juniper has been found satisfactory as a source of slats for lead pencils recalls some of the work that has been done in an effort to find ways of producing red wood for pencil needs. The famous Tennessee cedar has long been the source of our pencil wood, but that is practically exhausted. Americans especially have come to prefer pencils the wood of which has a reddish color, and at one time a moderate-sized plant was successfully conducted with profit in the business of impregnating white cedar with dyes to produce a red shade. The pencil slats were put into a vacuum apparatus where the moisture was gradually withdrawn from them. While still under a vacuum a solution of dye was admitted and a condition from vacuum to pressure gradually brought about. At the conclusion of this treatment the wood was withdrawn, the excess dye liquor removed, and the material dried. In this manner the whim of the customer was gratified.

It seems that the juniper is also a reddish wood and that for several years the southern juniper has been used to piece out the Tennessee cedar. Even fence rails and posts have been called into service in meeting this need.

It appears that the wood of the juniper is reddish-brown in color and that in a majority of trees a bolt of wood six to eight feet in length, can be secured free of limbs. The tree has no tap root and frequently the largest trees can be pulled over by a team of horses.

SULPHUR VS. PYRITE.

FOR many years Spanish pyrite has been the preferred source of sulphur in the manufacture of sulphuric acid, due to the value of the by-products, and to the low rate of transportation which applied in bringing it to our country. Changed conditions since the war appear to be bringing about the substitution of sulphur for the pyrite for such purposes. There is a saving in the labor which must be expended in the mining, transportation, and handling of the pyrite and with increased wages, this has become a controlling factor. Trans-Atlantic transportation is also much more expensive than formerly. The sulphur mining operations in Texas and Louisiana have reached the point where pure sulphur can be sold in competition with pyrite and now that new deposits have been opened up and the Louisiana mines appear to be producing without signs of exhaustion, the sulphur companies are preparing to compete for the custom which heretofore has gone to lower grade material. These companies made large investments in order to supply the sulphur necessary for acid demand for war activities, and their decision to seek markets heretofore held by pyrite may be due to a desire to earn a return on invested capital.

THE SOUTHERN FOREST CONGRESS.

A NUMBER of conferences are being held composed of foresters and the various lumber and timber interests, to discuss our timber situation and the possibility of formulating a national forest policy which will ensure suitable supplies of timber in years to come. The Southern Forest Congress was held, beginning January 28th, in New Orleans, and they brought out the necessity of not only discussing the situation that all may be informed, but of actually doing something. The importance of reforestration, especially of those cut-over lands not suitable for agricultural purposes, was outlined with reference to agriculture, to naval stores, to the pulp and paper industry, to stock raising, and to the miscellaneous transportation and public interests of the community. The diversity of uses which chemistry makes of cellulose, one of the cheapest forms of which is wood, has been the subject of frequent discussions, so that the chemist is interested in the continuation of this comparatively inexpensive raw material. We have been taught for so long that our forest resources are inexhaustible, that many find it hard to believe that under present methods practically all of the merchantable timber will have been cut out of the south within fifteen or twenty years. In a few instances reforestration, either by the self-perpetuation of the forest or by setting out trees, has been undertaken, and at least one corporation is convinced that proper grazing methods will enable the cost of reforestration to be met by the sale of cattle. Four acres of cut-over pine land will maintain a steer for nine months and heavy grazing is essential for the removal of sage grass which is detrimental to the young forest. In the olden days in the west it was estimated that from sixteen to twenty-five acres were required per head of cattle, so it seems evident that the stock can be fed in the open areas or on dry feed for the remaining three months of the year and still leave a handsome profit.

A tract of cut-over land which is being employed for the production of a second forest is expected to be worth $450,000 sixty years from now and to produce a sum sufficient to meet taxes, over head, and seven per cent interest upon the investment meanwhile. This income will be derived from live stock operations and the sale of various classes of sticks, posts, and poles removed in the course of the necessary thinning.

It seems that only two advances have been made in the turpentine industry in the last 300 years. One of these was the adoption of the gutter and cup method for the tapping of the trees, and the other the substitution of copper for iron stills in the plants. Some valuable work has been done in Florida on problems in the turpentine industry, but there is obviously a great opportunity for coöperative research.

The Forest Congress adopted resolutions condemning wasteful practices, the approval of the plan to establish two forestry experiment stations in the South, and the setting up of non-political state forestry departments in different states, with adequate appropriations to carry out a sustained program of useful work. The necessity of devising special tax laws for lands to be devoted to reforestration was recognized, as well as a more careful study of methods of taxing timber lands, based upon the yields of timber, and the separation of land values from timber values.

Research Work of the United States Bureau of Standards

Notes Specially Prepared for the SCIENTIFIC AMERICAN MONTHLY

STANDARDS OF GAS SERVICE.

FOR some years the Bureau has actively coöperated with the gas industries in various sections of the country. During the war, this assistance frequently took the form of extensive surveys of conditions existing in various cities and towns, with a view to regulating the gas industry so as to bring about the necessary alterations in service imposed by war conditions with the least hardship to the gas companies and the public.

In 1915, the Bureau issued its circular No. 32—"Standards for Gas Service" which may be said to have been the recognized authority in this country on the subject since that date. However, in the four years that have intervened since the circular was issued, fundamental changes have taken place in the gas industry. The use of gas for cooking and in industrial appliances has greatly increased, while its use in open flame burners, for purposes of illumination, has much diminished. Likewise developments have taken place in gas-making processes and changes have come about in the quality of gas-making materials available, and the general alteration of economic conditions brought about in part through the war have introduced new factors which ought to be considered in any publication treating on the subject.

To meet these new conditions, the Bureau has entirely rewritten a considerable portion of this circular and the work would have been pushed to a conclusion some time ago had not certain of the war activities prevented its active prosecution. The new edition, which will soon be completed, will contain sections on the heating value of gas, its freedom from impurities, allowable gas pressure variations, gas meters and meter testing, general service requirements, enforcement of regulations regarding service, a form for service rules for use by regulating authorities, a discussion of present methods of manufacturing and distributing gas, as well as certain data which it is believed will be useful to those persons interested in gas-making and using.

The revised manuscript of this circular has been completed and will be brought up for consideration and discussion in the near future at a meeting of the Represenattive Committee of Gas Engineers. This committee has been formed from the leading gas engineers of the country and on it the Bureau of Standards is represented. In this way, those particularly interested in the manufacturing side of the proposition, as well as those best able to judge of the scientific side of the problem as a whole, will be able to go over the material contained in the article. After the suggestions and comments of the members of the committee have been given consideration, the circular will be completed and printed for distribution.

CONFERENCE ON INDUSTRIAL SAFETY CODES HELD AT THE BUREAU OF STANDARDS ON DEC. 8, 1919.

THE importance of standardization in safety work has been given a great deal of consideration of late, and in this work the Bureau has taken a leading part. It would appear undeniable that uniform regulation of industrial plants, from the point of view of safety, should be undertaken at once.

On December 8, 1919, a conference on Industrial Safety Codes was held at the Bureau of Standards and methods were discussed for developing a series of National Industrial Safety Codes, and for their introduction into use. It is the Bureau's desire to secure general coöperation in the preparation of these standards by those who will be most concerned with their application. Work of this sort to be effective must be participated in by all the interested parties, and the efforts of all concerned must be properly coördinated in order to insure that the set of codes drawn up will be applied uniformly in the different sections of the country.

An important result of the conference was the arrangement for a Joint Safety Code Committee on which the Bureau will be represented to recommend a list of codes which should have first attention, as well as the most suitable organizations for carrying out their compilation. The general sentiment, as recorded by a vote at the conference, is in favor of having the Bureau, in coöperation with the engineering societies and other bodies prepare standards in accordance with the methods of procedure of the American Engineering Standards Committee, and submit the resulting codes for the approval of that committee, in order to secure their general acceptance and use.

The Bureau is at present engaged in revising the National Electrical Safety Code, which was published in 1916, and it is hoped to issue a new edition within a few months. During December a draft of the code for Head and Eye Protection was issued and circulated among those interested, for criticism. The work on this code is practically completed and it is hoped to print the first edition in the near future. The work of preparing the National Elevator Safety Code, in coöperation with the American Society of Mechanical Engineers, is nearly completed and a final draft was prepared before the end of last year. It is now awaiting the approval of the committee which has had it in charge, the General Advisory Committee on Safety Codes.

STRAIN GAGE TESTS OF INDETERMINATE STEEL STRUCTURES.

IN previous notes, the system of taking strain gage measurements of reinforced concrete and tile structures was described. A similar method has been used in calculating the stresses in statically indeterminate steel structures. A prominent example of work of this kind recently undertaken by the Bureau is furnished in the elaborate strain gage investigation of the large fitting-out crane at the Philadelphia Navy Yard, the tests of which were completed last December. This crane has a capacity of 350 gross tons and is probably the largest in the world. Strain gage readings were taken on all the important members and the work was carried through to a successful completion despite adverse weather conditions. A similar investigation was made nearly two years ago on a revolving floating crane at Norfolk. The accurate determination of the stresses in such structures is a matter of greatest importance from the point of view of the designer and will permit the construction of such cranes with every assurance of their success in service.

VELOCITY OF FLAME PROPAGATION IN THE CYLINDER OF A GASOLINE ENGINE.

FOR many years automotive engineers have discussed the probable velocity of the flame in the compressed and burning gas in the cylinder of an internal combustion engine. Many have maintained that this velocity was comparatively low and that in a high speed engine, in order to obtain maximum efficiency and power, at least two spark plugs must be used. It has been maintained by these engineers that by igniting the mixture at two points in the cylinder, the necessary time for complete combustion would be greatly reduced as com-

pared with that needed when but one spark plug is used. However, until very recently, no measurements have been made in an actual engine and the determination of this velocity has always been considered to present extreme difficulties.

For several months, the Bureau of Standards has been investigating this subject. A single cylinder gasoline engine, the combustion space, valves, piston, etc., of which are identical with those used on the Liberty aircraft engine, has been employed in this work. Three spark plugs are placed in the cylinder; the first is used to ignite the charge and is connected to the regular ignition system of the engine, the other two plugs are connected at approximately the proper time to a source of direct current, the voltage of which is insufficient to break down the gap between the sparking points of the plugs while under comparison, but which is sufficient to cause a spark to pass as soon as ionization of the gap occurs due to combustion of the surrounding mixture. These spark plugs are so connected with an oscillograph that the time when the flame reaches them is recorded on a strip of photographic film. The distance between the plugs is accurately known and the speed of the oscillograph film is also easily determined. It is obvious, therefore, that by measuring the distance between the points on the film indicating discharge of current across the gaps, the average speed of the flame between these points may be measured.

Determinations have been made of the velocity of flame propagation under many conditions of fuel-to-air mixture ratio, compression, speed, etc. The velocity appears to vary greatly under different conditions and to increase as the flame spreads through the combustion space.

THE PARACHUTE'S WORST ENEMY.

By E. R. CALTHROP.

THE standard patterns of all its smaller military aeroplanes —the single and two-seater—adopted by the British Air Service, carry behind them a tail-skid that amounts to a gaff or fish-hook perfectly adapted for the express purpose of catching and tearing the top of a silk parachute body when, issuing in a flash from its container, it instantly takes on the speed of the air current and is swept under the fuselage to far beyond the tail in less than a second. True that in the great majority of cases the apex of the parachute body whips past the tail-skid with a sufficient margin of space to give ample clearance; but, in the churning cone of compressed air, shot rearwards by the propeller, and outracing the speed of the air current itself, there are whirlpools of boiling air which can play strange freaks with a material so gossamery and non-resistant as silk. A vertical air-whirl can suck up the top of the silk body right into the tail-skid, even when the airplane is flying on a level.

If at the instant of the parachutist's jump the tail of the aeroplane is accidentally lowered, instead of being elevated, as should always be the case for a demonstration drop, there is grave risk of the tail-skid dipping right down into the path to be traversed by the body, and ripping such a long slit in the silk panels as to increase the rate of the fall of the parachutist to a speed that is dangerous. The resistance of the parachute is obtained by the continuous gathering up and compression of air within the body, and its subsequent centrifugal frictional dispersion from the edge of the periphery. Once a rent is started in the body, the contained compressed air forces itself through it, widening it out, and the tearing of the silk is continued until stopped by the reinforced edges of the panel. If this reinforcement is also cut by the tail-skid the tear will extend to yet another panel, which will further increase the speed of the dropping parachute; the increased speed will augment the pressure of the enclosed air tearing through the rent, and as the hole widens the leverage is greater for further destruction. If more reinforcements are burst only a miracle can prevent a fatal accident. Such a miracle has happened, but we cannot depend upon a continuance of miracles.

An aeroplane man-dropping parachute has to be designed to be of the least possible weight compatible with absolute reliability in its functioning, and an area of spread sufficient to cover the weight of the heaviest user, and to give, in addition, a safe margin for those abnormal happenings in the air—such as down dunts and the furling of the periphery—of which we are only at the beginning of learning some of the secrets. The epicycloidal section of the body, as now designed, has had the combined objects of (a) using the smallest amount of silk —reducing cost and weight—to attain the desired resistance and carrying power, and (b) of equalizing the stresses on the silk so that every square foot of the body area is carrying an equal load. The silk has to be sufficiently strong to meet normal and abnormal stresses, and the seams of the panels in the body have to be so designed that they act as reinforcements in the transference of the resistance from the body to the rigging and thence to the load—the parachutist. It is in the delicate balancing of all these strengths and resistances that saving of weight has gradually been gained without loss of strength, or of speed and efficiency in functioning, of nearly ten pounds. The safety of the parachute and of the parachutist depends upon the delivery intact and the sure full expansion above him of this filmy silk dome. Is it reasonable that work of this delicacy should run the risk of being ploughed through by the shear of a tail-skid? When a parachute body is gashed in this manner, it is not due to a failure of the parachute to function. It is purely extraneous happening, quite outside of the action of the parachute, which can easily be avoided.

There is no necessity whatever for a tail-skid to take the shape of a gaff, or that there should be any projections at the tail of an airplane that could rip a silk body. There are many airplanes already in existence in which the tail-skid presents a smooth unbroken outline, continuous with the under profile of the fuselage, against which the silk body could be thrown up by an air eddy without the least risk of a tear occurring. In the same way there are many machines now existing with tail planes not set at right angles to the centre line of the fuselage, as is the case with so many British machines, but sloping to the rear at an acute angle, so that if the leading edge is struck by the top of a parachute body it could not lap over the aerofoil and run the risk of a breakage, but would be harmlessly deflected out of the way. With all obstructing projections behind the cockpit smoothed away, a parachutist, would always get safely away.

It is for the Technical Department of the Air Ministry to point the way. They have full control of the designs and specifications of all military machines, and what they order has to be carried out. If they lay down the law that behind the cockpits there shall be no projections or rugosities that can possibly in any circumstances arrest or tear a parachute on its release from its container, fire, breakages, and loss of control in the air will be met without trepidation, for the pilot will know that in the last resort there will be no difficulty oin getting away from his machine safely.—From *Aeronautics*.

MOISTURE CONTENT OF WOOD

EVEN after long exposure to the same atmospheric conditions, different pieces of wood do not have exactly the same moisture content. Variations of 2 per cent were recently found in red oak blocks stored under carefully fixed humidity conditions at the Forest Products Laboratory.

These moisture differences, unlike variations in strength, are apparently independent of the density of the pieces. In the laboratory experiments, the variation proved to be as great in blocks of the same density as it was throughout the lot of specimens. Moreover, the range in moisture content was the same in wood of low density as in wood of medium density or high density.